ANNALS
OF
The Entomological Society of America

Volume XX JUNE, 1927 Number 2

THE MALPIGHIAN TUBULES OF THE LARVA OF HEPTAGENIA INTERPUNCTATA, SAY.

Wm. S. Marshall,
University of Wisconsin.

The Malpighian tubules of the Ephemerida, both of the larva and the imago, have been described by a number of workers; as far as I have been able to ascertain there has not been any paper published in which one can find a detailed description of their structure either in the immature or the mature stage of these insects. These tubules in the May-flies assume, according to different observers, many forms; several have been described as filiform, others as similar in a general way to the ones described in the present paper. From both descriptions and figures it has been shown that in several species of May-flies the tubules are short and bent or coiled, or, in some species they assume a spiral form. The more detailed descriptions have shown that in many species each tubule consists of a distal, thicker and secretory, portion from which a thinner tube passes and enters indirectly or directly into the intestine. Tubules opening separately have been figured by Dufour (3) and Drenkelfort (2) but in most species it has been shown that they open into several common receptacula and that these open directly into the digestive tract; Leue (8) and Vayssiere (13). The short account of most of the quoted authors gives but a meager description; many, however, show the two above mentioned parts of each tubule and the spiral or twisted shape is commonly mentioned or figured. From these various accounts the one which most closely resembles the tubules of *Heptagenia interpunctata* is the figure given by Vayssiere (13) of *Heptagenia longicauda*.

In *Heptagenia interpunctata* there are eight tubes opening into the intestine and carrying the products of the Malpighian tubules; each of these, soon after its origin from the intestine, branches into two or three short and fairly wide tubes and these receive the ducts from the Malpighian tubules; there may be a secondary branching before the ducts are received. The number of tubules was not counted but there are many of them surrounding the intestine more being lateral than either dorsal or ventral. These eight tubes probably open into the intestine equidistant from each other although a couple of sections had the appearance of a lateral arrangement, four tubes entering each side. Drenkelfort (2) found that in *Siphlurus lacustris* there were more than a hundred Malpighian tubules.

Each Malpighian tubule is divided into a distal, secretory, part, the glandular portion, from which a tubular duct, somewhat longer than the active part, leads to one of the receptacula into which, as described above, they all have their outlet. The duct leaves the widest portion of the tubule near the center, really the end of the central coil.

The glandular portion of the tubule can, for the sake of description, be divided into two parts; there is first a long curved and bent distal arm which leads into the thicker and shorter central section from the end of which the duct leaves. This first arm is different in nearly every tubule but begins with a hook-like curve which, in some specimens, is more abrupt than in others. The terminal part of this hook is a little thinner than the rest but from the end the tubule gradually increases in diameter to reach its widest part just proximal to the beginning of the abrupt hook-like curve. This thicker part continues for about one-third the length of the tube which then gradually decreases in diameter. While but a single bend is shown in either the diagram (Fig. 2) or the drawing (Fig. 1) of the entire tubule this part rarely lies in one plane, even the hooked end, besides bending on itself, may also turn is some other way. The narrower portion continues for a short distance with only a slight curve and then the tube again turns abruptly on itself and for a short distance this part is more or less parallel to that portion of which it is a continuation. Soon after making this second abrupt curve the tube starts to make a spiral-like loop bending even more abruptly than either of the other turns, it also suddenly becomes very much wider; this is the beginning of the central portion. The increase in width in this central portion is very pronounced and, as it begins to abruptly widen, the tube turns sharply back on itself and so continues until it returns to where the wide central portion started; then it suddenly decreases in diameter to form the beginning of the duct. The duct then forms a nearly circular loop lying on the surface of the central part of the tubule and passing out to the convex margin of this portion, runs along this margin and returns

to where it had its origin; here it leaves the tubule and goes to one of the receptacula already mentioned. These Malpighian tubules vary considerably in shape and size as also in their twists and turns so that it is extremely difficult to write a description of any one of them, they all, however, conform to the same general plan. Each tubule can be divided into a long distal arm, the wider central portion and the proximal part, the narrow duct. An examination of the drawing (Fig. 1) and the more diagrammatic representation (Fig. 2) will, aided by the description, give one an idea of the general shape and the relationship of the different parts.

Having thus attempted to describe the Malpighian tubule from a surface view we will give what the study of sections shows us about its structure. In nearly all of the tubules stained and mounted entire something of the lumen of the tube can be seen and it is noticed that this hollow is very much bent as it passes down the tube, it is large and irregular and varies greatly in diameter. Near the distal end of the tubule the form of the lumen is fairly regular and its structure that of a simple tube; the wall here, as in the other parts, is fairly uniform and of a single cell in thickness; the cell boundaries could not be seen (Fig. 3). From a surface view the nuclei, as in the cells of most Malpighian tubules, are quite large and are circular or irregularly so in outline; from an edge view they are oval and vary greatly in size. All the nuclei in this distal end are large.

In the next section of the tubule, from the commencement of the thinner part to the beginning of the second turn, the nuclei are smaller. In this part a surface view of the tubule often shows many of the nuclei of a kidney-bean shape and adjacent to their concave surface there can generally be seen a portion of the lumen. In a whole mount this section of the tubule shows for some distance the nuclei arranged in a single row; from a more careful study we see that there is really a double row of nuclei but that the alternate ones are in a different focus. In this section of the tubule the lumen shows a distinct wavy appearance the bend going from one side to the other; this is shown (Fig. 4) in section to be due to the fact that each nucleus with a small amount of surrounding cytoplasm projects out into the lumen and bends it towards the opposite surface; passing along the tube the next nucleus is seen to be on the opposite side of the tubule and the lumen bends in the other direction. This arrangement gives the tubule from a surface view the appearance of having the nuclei alternating with the clear spaces (Fig. 3, to the right).

Structurally the tubule shows no modifications until it widens into the central part; this change appears, in a whole mount, to be abrupt but in sections it is seen to be gradual (Fig. 9). The nuclei in that part of the tubule before it widens into the central portion are the same as in the preceding part and the lumen continues its course of alternating towards one side of the tube and then towards the opposite one. The lumen throughout this entire part of the tubule is not nearly so regular as is shown in the two figures (4 and 9), it often pushes out much nearer the wall and forms irregular pockets between the nuclei

giving to some parts of the tubules, internally, a very irregular appearance; this is partly shown in the transverse sections (Figs. 5, 6 and 7).

The irregularities we have just mentioned in the shape and width of the lumen do not compare to what is found in the large central part where these changes in diameter are much greater. Here in both surface view and in sections it appears as if the hollow part of the tubule occupies, in sections, a large portion of the interior, or, in surface view it appears as large cracks between the nuclei. The cells of this central portion are larger than in any other part of the tubule but their nuclei do not show a corresponding increase in size. Sections through this central part if cut away from the center show the lumen as pockets pushing out between the nuclei towards the wall of the tubule (Fig. 10) and no doubt outlining the cell boundaries; or, nearer the median portion (Fig. 11) the true width of the lumen can be seen. We have already said that in the distal end of this central part the change from one part to the other was a gradual one (Fig. 9); at its proximal end, from which the duct arises, this is not the case and the change from the secretory part of the tubule to the duct is an abrupt one (Fig. 12). This change takes place near the concave surface of the central portion from which place the duct, lying on the surface of the central portion, passes to its convex margin near which it starts to turn and passes for some distance along the edge, then it gradually turns back again to near the place from which it started; in doing this it forms a loop and then passes away from the tubule towards one of the receptacula into which it opens. The duct shows no variation, except in width, throughout its entire length. From a surface view the nuclei are seen to be circular in outline and, in any one view, they often alternate from one side of the duct to the other; in many specimens each nucleus is seen to have a clear ring surrounding it (Fig. 14). In sections the wall of the duct consists of a thin layer of cytoplasm in which the nuclei, now seen from an edge view, are disk-like. Inside of this layer there is a thin lining, it often presents a shiny appearance as if it were cuticular.

A more detailed description of the tubule brings out some interesting points. The striated layer, rhabdorium, which is so characteristic for the mid-intestine and Malpighian tubules of insects is not present in the tubules of the larva of *Heptagenia interpunctata*, the adults were not examined and the presence or absence of this layer in the imago is not shown. Leue (8) in his work on the larva of *Heptagenia sulphurea* does not mention a striated layer and omits such a layer from his figure. McDunnough (9) working with *Chrysopa* found this layer in the tubules of the larva but not by the adult and Holmgren (6) records the absence of a striated layer in the Malpighian tubules of *Apion*. Most of the sections were stained only with Delafield's haematoxylin, a few were counter stained with Bordeaux red and in these it was quickly seen that the wall of the tubule, especially the central part, consists of two portions. The inner part of the wall bore the haematoxylin blue with a faint trace of the red but there was a fairly wide outer layer, widest in the middle of the central portion, which was of a much darker red; while best seen

in the wide central portion this darker layer extended to near the end of the arm. This darker layer has been shown on only four of the figures, 9, 10, 12 and 13. In the sections stained with Heidenhain's haematoxylin the outer border was also noticeable and darker than the remaining part of the protoplasm. This is the external striated layer but. as in this insect there is no inner one present, the word external could well be omitted. This layer showed a number of elongated clear spaces at right angles to the basement membrane; these pass through the darker layer and give to it its striated appearance; these have been described as the canaliculi. In *Heptagenia interpunctata* they are very distinct in some specimens but not seen in others. This may be due to the different preserving fluids and stains used or to the time, relative to feeding, at which the insect was killed; than a stage in the activity of the tubule.

In very many of the tubules examined a second and smaller tube accompanied the duct and could be traced as far as the glandular portion of the tubule. This was probably a trachea to supply the tubule but a careful examination failed to show the presence of a taenidium; this might have been a tracheole from which the cuticular lining is absent.

The largest nuclei showed a pecularity in the presence in each of a large vacuole (Fig. 8) but never more than one in any nucleus.

A basement membrane is present as also a peritoneal covering, the latter can easily be seen especially so where the duct runs along the margin of the central body as this membrane lies external to the duct; it has not been drawn in any of the figures.

BIBLIOGRAPHY.

1. **Deegener, P.** Der Darmtractus und seine Anhange, in: Schroder, C., Handbuch der Entomologie. 2nd. Lieferung.
2. **Drenkelfort, H.** Zool. Jahrb. Anat. XXIX, 1910. p. 527.
3. **Dufour, L.** Recherches anatomiques et physiologiques sur les Orthopteres les Hymenopteres et les Neuropteres. Mem. de l'Acad. Sc., VII, 1861.
4. **Fritze, A.** Berichte d. Naturf. Gesell. Freiburg IV, 1888. p. 59.
5. **Heiner, H.** Jena. Zeit. Naturwissen. LIII, 1915. p. 289.
6. **Holmgren, E.** Entom. Tidskr. Arg. XIII, 1892.
7. **Joly, N., et Joly, E.** Rev. d. Sc. naturelles V, 1876. p. 305.
8. **Leue, F. W.** Arch. Naturgesch. LXXVII, I, 3 Suppl., 1911. p. 202.
9. **McDunnough.** Archiv. Naturgesch. LXXV, I, 1909. p. 313.
10. **Popovici-Baznosanu, A.** Arch. Zool. Exper. 4 ser. V. 1906. Notes et Rev. p. 56.
11. **Samson, K.** Zool. Jahrb. Anat. XXVI, 1908, p. 403.
12. **Schindler, E.** Zeit. wiss. Zool. XXX, 1878. p. 587.
13. **Vayssiere, A.** Ann. Sc. nat. 6 ser. XIII, 1882. p. 1.
14. **Vayssiere, A.** Ann. Sc. nat. 7 ser. IX, 1890. p. 19.
15. **Veneziani, A.** Redia II, 1904. p. 177.

EXPLANATION OF PLATE VIII.

Fig. 1. Surface view of a Malpighian tubule. × 280.

Fig. 2. Diagrammatic view of another tubule. In this and the preceding figure only a short piece of the duct is shown. Both figures show the long distal arm, the thicker central part and a portion of the duct including that part which forms a loop over the surface of the central body.

Fig. 3. Longitudinal section through the distal end of the arm. To the left the section is cut through the center of the tubule, to the right the section is almost a surface view. × 740.

Fig. 4. Longitudinal section of a portion of this arm taken from the narrower part. × 740.

Figs. 5, 6 and 7. Transverse sections through different parts of this armlike part of the tubule. All × 740.

Fig. 8. View of one of the large nuclei to show the contained vacuole. × 1700.

Fig. 9. Section through the proximal end of the arm where it enlarges to form the wider central part of the tubule, this latter portion is only in part outlined. Dt., duct. × 740.

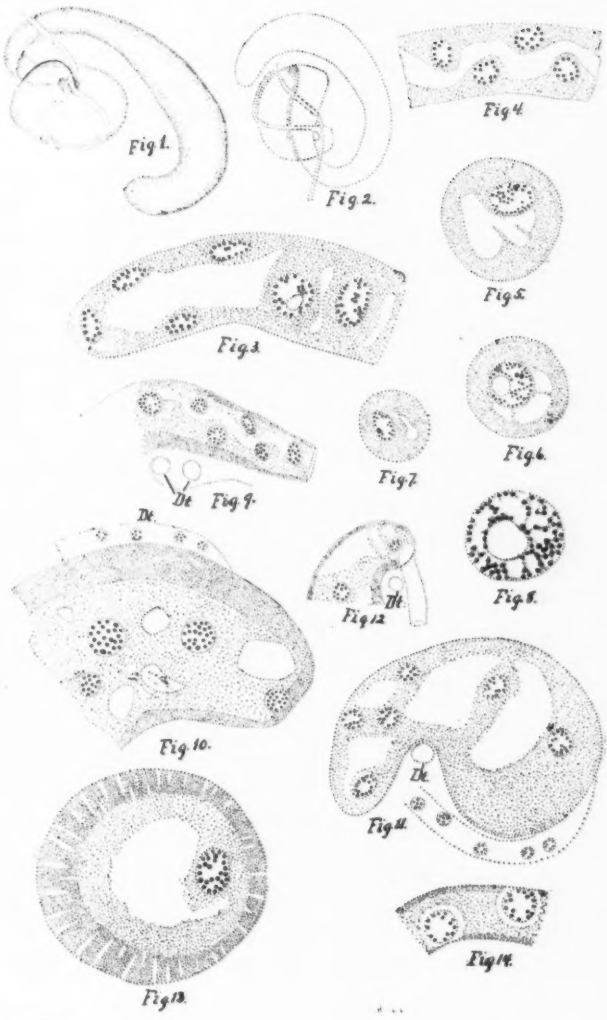
Fig. 10. Longitudinal section of a part of the large central portion of the tubule. This section is cut between the center and outer surface and shows only in part the lumen which is represented by the five areas not stippled. Dt., duct. × 740.

Fig. 11. Another section, more median, of the same part. To the left the section is cut through the center of the tubule, to the right it is more of a surface view. × 740.

Fig. 12. The proximal end of the central portion showing the origin of the duct. Dt., transverse section of another part of the duct. × 740.

Fig. 13. Transverse section through the larger central region. This section as well as sections 9, 10 and 12 show the darker external striated layer. In this section, which is a higher magnification than the others, the canaliculi can be seen in this outer layer. × 1100.

Fig. 14. Surface view of a small portion of a duct. × 1700.



Wm. S. Marshall

THE DEVELOPMENT OF THE CASTES OF BUMBLEBEES (BREMIDÆ: HYM.)*

THEODORE H. FRISON,
Illinois State Natural History Survey, Urbana, Illinois.

A. INTRODUCTION.

Published statements regarding the development of the workers, queens, and males of bumblebees are almost as varied as the total number of articles in which mention is made of this phase of their biology. Many investigators have touched upon this subject, but the writings of Reaumur (1742), Huber (1801), Lepeletier (1836) and Hoffer (1881-82) have exerted the greatest influence upon ideas which have attained more or less general acceptance. The most recent publications which give information concerning this subject are those of Sladen (1912) and Armbruster (1914). A review of this existing literature shows that many of the statements represent that which is purely inferred by analogy with the honeybee. Some statements are given which are based upon studies of bumblebee colonies, but unfortunately in most instances the observations were not thorough or frequent enough to prove the facts as they are stated.

The difficulty of absolutely tracing the life-history of a particular individual from egg to adult has been one of the chief obstacles leading to much of our misunderstanding of the life of the social bees. Although it has not been recognized, in some respects colonies of bumblebees offer a better opportunity than do colonies of honeybees for the study of caste and certain phases of sex determination among the social Hymenoptera. This is because bumblebee colonies are often so small that a close watch may be kept of the development of all the individuals and cells constituting a colony. In my experiments, the development of almost all the individuals of a single colony was often followed from the time when the first eggs were laid until the last adults emerged. Of course I do not mean to

*Contribution from the Entomological Laboratories of the University of Illinois, No. 1121. Extract number six from a thesis presented to the Faculty of the Graduate School of the University of Illinois in May, 1923, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

imply that all stages of all individuals in that colony were under observation every minute of the day; but merely that so many observations were made and such a close watch kept on all individuals that the results obtained would not be greatly modified by continuous observations. The difficulties standing in the way of continuous observations of social insects have been well pictured by Wheeler (1922). In this paper no attempt has been made to enter into a detailed discussion of the merits or weaknesses of the Dzierzon theory and the views of other investigators. It suffices for the present to state the facts, as I have found them, regarding the development of workers, queens, and males of bumblebees.

B. Caste of Progeny of Over-wintering Queens.

Let us first consider whether the over-wintering female bumblebee queen is capable of producing both males and females, without regard to the difference existing between females—workers and queens. In the light of that which we know to be true of insects in general, it may seem strange that there should exist any doubt as to this matter. The presence of certain small females—commonly referred to as workers—complicates such a problem as this in the case of the social bumblebees. Huber (1801) tells us that certain of the workers are surrounded by males produced in June and that these workers then become fertilized by these males and lay eggs which produce another brood of males. These latter males, in turn, fertilize the young queens which are produced in the latter part of the season. The fact that eggs laid by workers are generally assumed to produce only males is suggestive of the possibility that the males are entirely the product of worker eggs (Coville, 1890). In keeping with this view it is interesting to read recent statements of Friese (1922) that "die Eier für die Männchen von den grossen Arbeiten im Juli als unbefruchtete gelegt werden" and in another place that "In betraff des Verwandtschaftsverhältnisses würden demnach die Männchen eines Hummelnestes die Enkel der alten Nestmutter sein, die jugen Weibchen wie alle Arbeiter dagegen ihre Töchter sein."

Considerable evidence was found during the course of my studies in 1917-1920 that eggs laid by the over-wintering queens were capable of producing both males and females (workers and

queens). This was found to be true in the case of several species (*B. vagans* F. Sm., *B. impatiens* Cress., *B. bimaculatus* Cress., *B. americanorum* Fabr., and *B. auricomus* Robt.) of bumblebees, colonies of which I had under close observation. The fact that workers (females) are the first bees—there may be occasional exceptions—to appear after the queens have established their nests in spring, is in itself almost sufficient evidence to prove that the queens produce these small workers of female sex. Further proof of this lies in the fact that many nests have been found in spring or early summer which contained only workers. Finally, my experiments in rearing colonies under controlled conditions leave no possible doubt of the fact that the over-wintering queens can lay eggs which produce females. Obviously, then, since the first progeny of over-wintering queens are normally, if not always, workers (females) our discussion has mainly to do with whether or not the queen is capable of laying eggs which produce males. As already indicated from statements in our literature, the occurrence of workers in the nests somewhat complicates the proof that the queens also produce males, even though it is that which we would naturally infer.

In my experiments ample evidence was obtained to prove that males were produced by over-wintering females or queens. In the first place, many of my colonies were subjected to two or three examinations a day and a detailed record kept of the number of eggs laid and the sex or caste of the individuals ultimately produced. In these experiments the condition of the queen was continually observed and a careful watch was made for egg-laying workers (unfertilized small females). It should be stated before going further with this discussion that egg-laying workers, as previously reported by others, do occur in the nests of bumblebees. By carefully checking up the number of eggs laid during the day, a good indication may be had of whether an egg-laying worker exists in the nest. Furthermore, the actions of egg-laying workers in a nest are so similar to those of queens relieved of almost all duties except egg-laying, that such workers are readily noticed by one acquainted with the habits of bumblebees. I have not found egg-laying workers, however, to be as common in the nests of bumblebees as some writers report, and in normal colonies which possess an active laying queen, few workers become egg-layers during the fore and middle periods of the existence of the colony.

In many experiments where it was reasonably certain that egg-laying workers were not present, and that the queens were functioning at a normal rate for their species, eggs laid by the over-wintering queens produced males. Under normal conditions in temperate climates a queen does not lay eggs which produce males until a goodly number of female eggs have been laid. The time at which the male eggs appear in a normal colony of bumblebees has somewhat of a correlation with the fecundity and the seasonal adjustment of the species. Queens of *Bremus bimaculatus* have a comparatively low fecundity and a restricted period of productivity. In such a species as this, the eggs which produce males may be laid by the queens the last of May and not infrequently in June. In the case of *Bremus americanorum* and *Bremus impatiens* we have queens with a comparatively high fecundity and a long seasonal adjustment. The queens of these latter species usually do not lay eggs which produce males until the middle of July, and the larger number of them are laid in August.

The fact that males and queens come from cocoons in the same cluster or unit group has been cited as proof that both males and queens are produced by the mother queen. This may not be the case, because larvæ originating from several egg cells may eventually merge and form one group of larvæ (they may be of the same size or different in size) as Wagner (1907) mentions and as I have often observed. It might be assumed, also, that the adults reared from eggs laid in a single cell would prove whether males and females are both produced from eggs laid by the queens. It has been my experience, however, that most of the eggs laid at one time and in the same cell produce adults of the same sex. In Experiment 6, 1919, (*B. impatiens*), over two hundred eggs were laid which produced workers (females), before any eggs were laid which produced males. Sladen (1912) has mentioned that in some nests he had under observation that no males were ever produced. In view of such conditions as these, it is evident that statements based on the observation of few egg cells might easily lead to erroneous conclusions. Males and females which are the product of eggs laid in the same cell (sometimes this happens) are most frequently found during the "climax" period of the development of the colony. This, naturally, is due to the fact that almost all of the eggs laid in the early history of the colony

are of the same sex and that those laid at a later date produce the males and females. Armbruster (1914) even questions whether rearing males and females from eggs in the same cell proves anything, because of the fact that workers might be responsible for some of the eggs (the male eggs). In my experiments I have never seen workers open a closed egg cell and lay eggs in it or attempt to lay eggs in the same cell in which a queen was laying eggs. According to my experience, a queen never opens a closed cell for the purpose of laying additional eggs in it and I am extremely skeptical as to whether the workers have any such instinct and thereby differ from the queen. Hoffer (1881-82) has made a statement to the effect that queens do lay eggs at intervals in the same cell, but my observations indicate the contrary. Wagner (1907), also, has questioned the correctness of this statement by Hoffer. Certainly, if such an event ever occurs it is the exception rather than the rule.

The fact that in my experiments males developed from eggs laid by queens, when no evidence existed indicating the presence of an egg-laying worker in the nest, makes it obvious that eggs laid by the queens are capable of producing males. Lastly, it can be added that in certain of my colonies I have actually observed the queens lay eggs which eventually produced males. This corroborates the opinion of Hoffer (1881-82), who (aside from certain other statements) emphatically states that the queens can lay eggs of all castes. Sladen (1912) also credits the queen with producing both sexes. If workers alone were charged with the responsibility of producing males, there would be need of some sort of further specialization among bumblebees to prevent all workers from assuming this function, if the colonies were ever to attain large size and preserve a reasonable proportion between the female and male castes. The abundance of egg-laying workers in a normal colony seems to me to have been over-estimated, and the observations indicating such conditions based upon colonies whose natural routine had been greatly disturbed. My experience with egg-laying workers has been in the main quite similar to that of Sladen, who writes that "unless the queen is unprolific, or dies early, the workers produce very few offspring, indeed in many nests they produce none."

In the arctic regions only small colonies of bumblebees are developed because of the short season, but nevertheless males are quite abundant. In fact, workers of some of the most northern species are much less common than are the males. Sparre-Schneider (Friese, 1902) failed to find the workers of one species of bumblebee, *Bremus kirbyellus* (Curtis), during a long residence in the arctic regions, and the workers of another species, *Bremus hyperboreus* (Schönheer), were extremely rare. These facts, though not conclusive (the workers may have remained in the nest, etc.), strongly indicate that queens produce both males and females. In the case of the social parasite *Psithyrus*, likewise a member of the Bremidæ, both males and females are produced by the over-wintering females as is indicated by the fact they emerge about the same time. The production of the males, in such a case as this, can be explained in no other way than that they were produced by the over-wintering females.

C. Caste of the Progeny of Egg-laying Workers.

Granting that the queens which establish colonies in spring produce males and females, the question now arises as to the occurrence of egg-laying workers and the sex of the individuals which result from such eggs. The presence of egg-laying workers in nests of bumblebees has been observed by Huber (1801), Lepeletier (1836), Schmiedeknecht (1878), Hoffer (1881-82), Sladen (1912), Armbruster (1914), Bachman (1915), and Plath (1924), and reference to their presence has been mentioned by many writers. During the course of my studies it has been my good fortune to obtain considerable information relating to workers which lay eggs. My proof that workers lay eggs is based on the fact that I have dissected certain worker suspects and found eggs in their ovaries, seen workers lay eggs, and studied colonies where the conditions were such that the eggs which were laid could only have been laid by workers. In one colony of *Bremus bimaculatus*, Experiment 1, 1919, six workers were discovered to have assumed the roll of egg-layers a few days after the disappearance of the queen from the nest. In this nest a worker was once observed in the act of laying eggs in a cell which she had just made. The instinct of making egg cells is not suddenly developed in the workers because workers were frequently seen which I had no reason to suspect as being

egg-layers, aiding the queens in the construction of egg cells in which the queens later deposited eggs. The six egg-laying workers found in Experiment 1, 1919, were the most ever observed at one time in a single colony. Within a period of thirteen days, these workers laid nearly fifty eggs. From one to three eggs were laid in a cell. The only difference that I could see between these eggs and those laid by the queen was that they were smaller. The same was true, also, of the size of the eggs cells.

As already stated, egg-laying workers are usually not found in nests during the early part of the development of the comb. In the case of *Bremus bimaculatus*, the colonies of which early reach their "climax" development and produce males and young queens in June and July, egg-laying workers were found as early as June. In a colony of *Bremus impatiens* which produced a majority of its males and young queens in August and September, egg-laying workers were not found until September. In a colony of *Bremus vagans* seven eggs were found one day which had been laid in an irregular manner in an old male cocoon, partially filled with pollen, and capped on top with a composition wax-pollen covering. There was abundant evidence to prove that these eggs were laid by a worker. Without going into further detail, it is sufficient to record that egg-laying workers also were observed in the nests of *Bremus americanorum*, *Bremus auricomus*, and *Bremus separatus* (Cresson). The fact that I have observed egg-laying workers in four different subgenera of *Bremus* is quite indicative that parthenogenesis is not confined to any particular group of bumblebees. It is easy to demonstrate that workers can lay eggs by removing several workers from a nest and placing them in an artificial nest exactly like that provided a queen in spring. Under such conditions workers will frequently make egg cells and lay eggs. Plath (1924) has likewise found that workers will construct egg cells and lay eggs when deprived of a queen. Whether females of *Psithyrus* which have not been fertilized are capable of laying eggs has not been established, but in view of what has been found true of *Bremus*, it is not improbable. The seasonal adjustment of the species in temperate regions, however, is such that parthenogenesis can not play an important part in the development of the males of *Psithyrus*.

As stated before the presence of numbers of egg-laying workers in a colony, judging from my observations, is certainly abnormal. Furthermore, the presence of egg-laying workers seems to be correlated with the failing fecundity of a queen, the loss of a queen, or other conditions which are leading to the demoralization and disintegration of the colony. For instance, in Experiment 6, 1919, (*B. impatiens*) egg-laying workers were not noticed until after the death of the queen on September 7. In Experiment 11, 1917, (*B. bimaculatus*) workers removed from the colony and placed in nests with young queens developed egg-laying habits. This was evidently due to the abnormal conditions to which the workers were subjected. An excellent illustration of the effect that the loss of a queen has upon workers in respect to egg-laying was shown in Experiment 13, 1917, (*B. bimaculatus*), and other examples of similar nature might be cited. In colonies which have comparatively very prolific queens, many adults are produced before males appear or before egg-laying workers are found in the nests. In Experiment 6, 1919, (*B. impatiens*) over two hundred workers were reared before any males appeared, which indicates that there is something about the presence of an active and prolific queen which prevents workers from playing a prominent part in egg-laying. The same condition is noticeable in strong colonies of *B. americanorum*, which may produce a couple of hundred workers before any of them are found trying to act the part of a queen. If one removes the queen of *B. americanorum* from a nest before many workers have been reared, certain workers will soon lay unfertilized eggs.

An egg-laying worker may be readily detected by her worn appearance and actions. The presence of small egg cells and but few eggs in a cell (where the queen has the habit of laying many eggs in a cell) are likewise good indications of the presence of egg-laying workers. Queen bumblebees which are mothering a colony often look quite different from the new queens in the fall. This is because the abdomen of such a queen becomes somewhat distended and much of the pubescence on the head, thorax and abdomen may be lost. The same condition is noticeable in egg-laying workers. Of course, workers not laying eggs may lose some of their pubescence, but the distended abdomen of an egg-laying worker is quite characteristic and noticeable. The habits of egg-laying workers are quite similar

to those of queens after they have quit foraging for nectar and pollen. Accordingly, such workers remain in the nest most if not all of the time and crawl about and brood on portions of the comb, particularly upon cells containing their own progeny. When colonies containing such workers are disturbed, these egg-laying unfertilized workers buzz excitedly and race about over the comb, but rarely fly forth in its defense. The fact that these laying workers so closely mimic in their actions the larger queens may be the reason why all workers do not become egg-layers when the queen fails. In other words, the first few workers to start laying eggs and assume the roll of queens may serve in a measure to prevent other workers from taking on this function. I have never seen more than six laying workers in a nest at one time.

Reference has already been made to Huber's idea that certain workers are fertilized by males produced in June, and that the males resulting from this union mate with the young queens. Our earliest american student of the biology of the bumblebees was skeptical of this notion (Putnam, 1865) and nothing has been found in the course of my studies to indicate that such an intricate and indirect system for perpetuating the species of bumblebees exists. Many reasons could be advanced to seriously discount Huber's statements and mention will here be made of several of the most obvious ones. In the first place no males occur in most nests sufficiently early in the season to fertilize the first so-called small queens (workers). Secondly, I have never seen males mate or attempt to mate with small workers at any time. Though such a thing may happen, it certainly is of rare occurrence (Sladen reports one instance of this). Lastly, if these workers are fertilized by males, why do all the resulting progeny happen to be males? Though it seems to me that Huber is entirely wrong in his indirect system of queen fertilization, I am not challenging the idea that males resulting from worker eggs are capable of fertilizing young queens. Males reared from worker eggs have never been observed mating with young queens, but there is apparently no reason why they are incapable of doing so. No morphological differences between males reared from worker eggs and males produced from eggs laid by queens were apparent.

Granting the fact that certain workers lay eggs, we are now confronted with the question as to whether these eggs produce

adults, and as to their sex. Most biographers of bumblebee life mention that the eggs laid by unfertilized workers produce males. In view, however, of the careful and continous observations which are necessary to definitely prove this point and the methods of study pursued by previous writers, it seems that most of these statements rest upon very little real evidence. Though as stated, most previous writers have held the view that worker eggs produce only males, we find such an able and keen investigator as Hoffer maintaining that under certain circumstances large workers (Hoffer calls them small queens) lay eggs from which workers, queens and males develop. He fails, however, to tell the circumstances which bring this about and whether these particular females are fertilized or not. Schmiedeknecht has mentioned also that large workers now and then hibernate and states he believed that they were capable of starting colonies. Schmiedeknecht's statements may be dismissed as mere opinions, and furthermore the bumblebees that Schmiedeknecht considered as large workers may in truth be entitled to be classed as queens of less than average size. It should be stated here that young queens collected in fall nearly always appear smaller than queens found in the field in spring. This is because the abdomens of queens are more distended in spring than before hibernation. Furthermore, as will be presently pointed out, it is a question just where to draw the line between large workers and queens.

In my experiments, all adults unquestionably reared from worker eggs were males. In Experiment 5, 1917, (*B. bimaculatus*) the mother queen died during the last of July. Workers soon began laying eggs and several males emerged between September 6 and 8 which were the product of these worker eggs. The same thing happened in Experiment 13, 1917 (*B. bimaculatus*). In every case that came under my observation the adults reared from worker eggs produced males. The same objection against claiming on the basis of these data that all worker eggs of bumblebees are of male sex can be advanced in this case as has been done against similar rearings of males of *Apis mellifica* (Linn). In my colonies of bumblebees, the greatest part of the eggs laid by workers failed to produce adults and accordingly the sex of the eggs which failed to develop is unknown. However, no evidence was found that any workers or queens were ever developed and accordingly no evidence

discovered to support Hoffer's statement that under certain conditions worker eggs might produce females. In view of my studies I believe that all adults originating from unfertilized workers (such was the condition of the workers in my experiments) are males. That the european species studied by Hoffer are not much different biologically from the species occurring in Illinois will be brought out in another paper. Sladen, who studied many of the species studied by Hoffer, says that there is "ample evidence to show that the laying workers are virgins, and this explains why they produce males only." Armbruster (1914) also says that the eggs laid by workers of *B. pratorum* (Linn.) produce males. Though most of the eggs laid by workers in my colonies failed to produce adults, the conditions in my colonies at the time the egg-laying workers appeared and when eggs were laid were such that an explanation of their failure to produce adults does not necessarily lie in theoretical realms. As already stated, egg-laying workers in a colony of bumblebees are usually the sign of the failing prolificness of the queen, her loss, or the general disorganization or disintegration of the colony. The death rate of ordinary workers rapidly reduces their number after a colony has reached a stage where no more females are produced. This, coupled with the fact that workers with egg-laying propensities are strongly inclined to remain in the nest and not forage for provisions, normally hinders the rearing of adults from worker eggs. Often, even the young progeny of a failing queen, or those of a queen which has recently died, may succumb to the unfavorable conditions resulting from such a condition. The theoretical assumption, however, that some eggs laid by workers fail to develop because of inherent conditions is still not entirely eliminated. Certain experiments aiming at the rearing of a greater proportion of worker eggs are being planned by the writer.

D. Influence Upon Sex by Larval Feeding and Egg-cell.

Considerable evidence was obtained that larval feeding was not responsible for sex. There are but two ways by which such differences as exist between males and females can arise: either the eggs are inherently male and female when they are laid or the larvæ are reared under conditions which influence the

developmental stages so that either one sex or the other is produced. In the case of bumblebees the only environmental factor which could possibly exert such a marked influence would be feeding, since all the other factors are practically the same within the nest. In fact, male and female bumblebees develop side by side under similar conditions of temperature, humidity, position on comb, etc. That quantitative feeding does not determine the sex of bumblebees is indicated by the fact that in my colonies adults of one particular sex did not invariably result from undernourished or poorly cared for larvæ; and the reverse of this, that highly nourished and well cared for larvæ do not invariably produce adults of the same sex. Small or even tiny males are sometimes produced in a nest of bumblebees as well as various sizes of females. When males much below average size were reared it was found that the larvæ which produced these males had been invariably subjected to unfavorable conditions which caused the larvæ to receive insufficient nourishment. For instance, diminutive males were often reared from larvæ whose cells occupied a position on the comb less frequently visited by workers than certain other parts. Small males were also encountered in nests when a colony had become disorganized and was breaking up, a condition which resulted in the larvæ existing in the nest at the time not being properly supplied with food at all times. I have reared under-sized males from colonies of *B. impatiens*, *B. bimaculatus*, *B. vagans*, *B. separatus*, *B. auricomus*, *and B. americanorum* and in all cases the cause for their development could be diagnosed as malnutrition. In figures 1, 2, 3, and 4 are shown the range in size of males of the same species. Though the males of any species of bumblebee produced under average conditions have about the same general size, all different sizes as just pointed out, may occur within the same nest. When we consider the evidence presented by parthenogenesis and that which is given under a discussion of the cause of polymorphism in females, there seems slight doubt but that males and females result from differences in the character of the eggs and that sex is not influenced by feeding, environmental conditions, etc.

In connection with the problem of sex determination in the case of the honeybee, it has been stated that the size of the cell influenced sex. No difference was observed in the shape

or size of bumblebee cells which (as shown by subsequent rearings) held potential male and female eggs. Furthermore, as already mentioned, males and females sometimes developed from eggs laid in the same egg cell. Such an explanation as the size or shape of the egg cell can therefore be easily eliminated as a factor influencing sex among bumblebees.

E. Cause of Polymorphism Among Females.

I have repeatedly studied large series of queens and workers (females) of various species and have failed to find any pronounced structural differences between the forms of the same sex such as are found in the case of ants and termites, and to a less extent usually between the queens and workers of *Apis*. In fact, the only discernible external difference is one of size. Physiologically and psychologically the workers are apparently nearly duplicates of the queen, since they possess almost all of the instincts of a queen, are capable of doing most of the things she does and are even capable of laying eggs which produce adults. Hence, polymorphism as it finds expression among the bumblebees, has mainly to do with size. Of course, the time and circumstances attending the production of the small workers causes certain elements of their behavior to stand out more sharply than those of the queen. Thus, the small females appear to be more specialized for foraging for pollen and nectar and for caring for the nest in general,—hence the name *workers*.

Workers are commonly spoken of as forming two classes, namely, large and small workers. Such a division is purely arbitrary with the recorder, for almost every possible variation exists in size from the smallest to the largest workers, and often in the case of some species to the over-wintering females called queens. In other words, the terms large and small worker, as applied to bumblebees, are simply convenient descriptive terms for use in describing the size of females which are not large enough to be called queens (therefore not capable of establishing normal new colonies). One might with propriety list the workers found in a single nest as tiny workers, small workers, large workers, very large workers, and so on. In my own papers the practice has been followed of simply referring to workers as forming two main overlapping artificial groups: large and small workers. Also, the term *queen* has been used solely to refer to those females which are capable of mating,

hibernating and of producing new colonies and adults of both sexes. In figures 1, 2, 3, and 4 are shown a series of workers of various sizes of different species and also females which have attained sufficient size to be considered as queens.

If we grant that males and females of bumblebees result from a hereditary influence, the question arises as to whether the polymorphism witnessed in bumblebee females is hereditary. We now know that in certain groups of social insects, as termites which have developed an elaborate caste system, that the castes may be determined to a certain extent in the egg stage. The same is said to be true of the ants. In the case of *Apis mellifica*, it has been demonstrated that eggs laid in queen cells, which under normal conditions would produce queens, if transferred to worker cells produce workers and *vice versa*. Even very young larvæ may be transferred with the same results as those obtained by the transfer of eggs. This is accepted as proof that in the case of the honeybee the difference between queens and workers (both females) is due to trophogeny. Mention has already been made of the fact that in the case of the bumblebees I have not been able to detect any differences between cells in which male and female eggs are laid. Accordingly, without a discernible difference in the size of the egg cells as a starting point for experimentation, the transference of eggs from one cell to another would be meaningless. Eggs can be transferred from one cell to another, however, as I demonstrated in certain colonies; even the eggs of another species of bumblebee. Many other facts have been found, however, which strongly indicate, if not actually prove, that the polymorphism of female bumblebees is due to feeding and that workers are merely miniature unfertilized queens.

As already stated, the females conveniently designated as workers vary greatly in size (See Figures 1, 2, 3, and 4). This variation is so great that there often may be produced in the same colony in the course of the season a complete transitional series from the tiniest female (worker) to the largest female (queen). In the course of my experiments in rearing colonies of bumblebees of various species belonging to different subgenera from their beginning to "climax" development, it was always observed that the first workers (females) produced were comparatively small, and that workers averaged larger and larger as the season progressed. Any number of my experiments

might be cited to illustrate this point. As a single illustration of this a part of the history of Experiment 11, 1917 (*B. bimaculatus*) will be related. The colonies of this species usually reach their "climax" development in Illinois in June or early July. In this particular colony the average size of the workers increased with almost every succeeding period of emergence. Finally there came a time, shortly after the middle of June, when it was difficult to determine whether I was dealing with young queens or large workers. This was immediately followed by the production of females of such large size that there was no question as to their being queens. In fact, subsequent mating and hibernation experiments proved that they were queens. This might have been considered as a case of coincidence if it had not been a matter of such general occurrence in my colonies. Of course small individuals were produced even in the middle of the season, but being few in number they did not affect the gradual increasing average in size. Such small workers produced in mid-season were usually found to have developed upon unfavorable parts of the comb. Colonies facing disintegration before their "climax" development is reached can not be considered in relation to this subject because they do not represent normal conditions.

To explain such variations in size as mentioned (Figs. 1, 2, 3, and 4) we must either assume a large number of differentiated eggs or the effects of environmental conditions. The fact that adults varying in size are produced from larvæ from the same egg cell; that female larvæ occupying an unfavorable position on the comb produce small workers; and that unfavorable conditions in the colony as a whole may cause small adults, all indicate that environmental conditions are responsible for the polymorphism exhibited by female bumblebees. Furthermore, the very number of different sizes of workers is sufficient to cause one to hesitate to ascribe the type of female polymorphism (size, not difference in structure) exemplified by bumblebees as being due to inherent differences in the eggs. As already brought out, the difference in the size of males is likewise due to conditions exerting an influence after the egg is laid—the result of feeding.

When we consider that tiny workers are reared from female larvæ as a result of malnutrition, the reverse conclusion, that the abundance of proper food causes the production of large

workers, is not illogical. A close study of colonies of bumblebees indicate that the production of large workers is due to feeding. The first workers are developed by the queen without the aid of workers. After the appearance of the first workers, the queen is aided with the rearing of the brood and in foraging by the workers. As the season progresses the workers become still more numerous and a surplus of honey and pollen is often found in the nests at this time. In other words, the increase in size of workers is correlated with conditions which suggest that the amount or quality of food is the factor which determines whether a female egg will produce small workers, large workers, or queens. Bumblebee larvæ are fed on pollen and a liquid which is supplied them from time to time by adults. The fact that the adults actually feed the growing larvæ from time to time, instead of entirely allowing the larvæ to develop in sealed cells containing food (mass-provisioning) is another feature suggesting that the size of females is due to feeding.

In order to properly conclude my arguments that feeding, either qualitative or quantitative, is responsible for the variation in the size of female bumblebees, I must introduce at this place some data regarding the fecundity of queens. I have found that *B. auricomus*, in Illinois, does not produce large colonies of bumblebees and that the chief reason for this is the low fecundity of the females. This low fecundity prohibits this species from producing a very numerous worker caste, but neveretheless large workers and queens are produced. There are other species in this state, however, which possess a comparatively high fecundity. This difference of various species in respect to fecundity is such, figuratively speaking, that a series of species from an extremely low to a relatively high fecundity may be arranged. The important point about such a series is that it is a transitional series and that high fecundity is associated with species producing queens after the appearance of numerous workers.

Though the biology of the bumblebees living in artic regions is not well known, my studies (Frison, 1919, 1921, 1922) of various collections of bumblebees from Greenland and the arctic regions of North America show that the worker caste is reduced in numbers. No species is known, however, which does not produce workers. As previously mentioned, Sparre Schneider in Tromso, Norway, after many years of collecting

failed to find workers of *B. kirbyellus*. Workers of this species are known, however, from arctic Eurasia and America. I have seen workers of this species from various parts of its range, but nevertheless the worker caste is truly reduced in numbers. In the arctic regions the season of bumblebee activity is short and the young queens are apparently oftentimes reared directly by the mother queen without the aid of an intermediary worker caste. This at first thought may seem to present a formidable obstacle in the path of the contention that feeding determines the development of the workers and queens. Such, however, is not the case. The small size of colonies of arctic species of bumblebees indicates to me a low fecundity of the queens, a state of affairs found to exist in the case of certain bumblebees in temperate climates which produce but small colonies. The very shortness, also, of the season which is favorable for brood rearing necessitates a low fecundity on the part of the queen. When we consider the time that is required for the development of the immature stages of bumblebees, the amount of food consumed by the larvæ, and the constant care they require (not necessary in mass-provisioning), a high fecundity on the part of the queen would be disadvantageous to arctic bumblebees. In order to cope successfully with their envirnment the arctic bumblebees must of necessity concentrate on rearing a few instead of many progeny, and evidently these larvæ receive the food and attention which larvæ of certain species with a high fecundity in temperate climates, as Illinois, usually receive after the production of a numerous worker caste. Though not forced by climatic restrictions to have a low fecundity, certain species of bumblebees with a low fecundity found in temperate climates evidently concentrate upon rearing a few individuals, some of which are queens, much after the manner of their northern relations.

Degree of fecundity, then, offers an explanation of the production of numerous workers by some species and only a few workers by other species. Furthermore, it enables us to explain the production of queens in all climates, and of all species inhabiting similar geographical areas regardless of any differences these species may exhibit in regard to the number of individuals produced.

A comparatively long time between periods of egg-laying and the laying of but few eggs at a time (attributes of low

fecundity) results in the queen, and later the workers, having more time to care for the brood than is possible where eggs are laid more frequently and in larger numbers (high fecundity). A prolific egg-laying queen of *B. impatiens* or *B. americanorum* during the last of July and early August can not possibly devote much time to her numerous progeny and they are mainly reared by the workers. When a queen bumblebee becomes merely an "egg-laying machine", as in the case of the queen honeybee, no or little time can be spent caring for her progeny. In such a case, then, it is logical to suppose that new queens will not be produced until an abundance of nurses and bountiful food supplies are present in the nest. Such seems to be the case and indicates that food or feeding governs the production of new queens.

No analytical studies of the liquid food supplied to bumblebee larvæ by adult bees were made. In the case of the honeybee, it has been established that a larva producing a queen is fed for a longer time more highly proteinaceous food than the larva of a worker and develops in less time than a worker. With the bumblebees on the contrary, the larvæ producing queens have a longer larval stage than do the larvæ producing workers. The proof of this statement will be presented in another paper. This suggests that in the case of bumblebees the difference between workers and queens may be due to quantity alone, rather than to a difference in the quality of the liquid food inserted into the larval cells. Structurally and biologically bumblebees display evidence that they are a group still in the course of active progressive evolution. In this connection it seems worth noting that there exists a greater average difference in size between the queens and workers of *B. impatiens* than with any other species of bumblebees that I have studied. This is correlated in this species with queens which have a very high fecundity and suggests that this species presents a rudimentary specialization of the more highly developed caste system of the honeybee.

F. Conclusion.

As is well known many theories have been advanced to explain the question of sex determination in the case of the honeybees. The theory of Dzierzon that male honeybees develop from unfertilized eggs has met with considerable

favor but Dzierzon's idea that all the eggs in the ovaries of the female are male has not met with equal approval. My rearings of male bumblebees from eggs laid by unfertilized workers agrees with that part of the Dzierzon theory which states that adults reared from unfertilized eggs are males. Additional experiments are planned with bumblebees to determine whether all eggs laid by unfertilized females are of the same sex (male). In the experiments reported upon in this article, as already mentioned, many unfertilized eggs failed to produce adults. Accordingly, it can not be stated without qualification (Phillips, 1915) that all unfertilized eggs are potential males. The Wagner theory that the size of the cell in which the egg is laid controlls the fertilization of the egg certainly can not apply in the case of bumblebees, for the egg cells are small structures and moreover no constant difference in cell width or size is discernible. Dickel's view that a fertilized queen honeybee can not lay unfertilized eggs will not coincide with the facts as they exist in bumblebees; namely, that fertilized queen bumblebees can lay eggs which produce males as well as females.

Another generally accepted hypothesis is that the queen can voluntarily control the issuance of sperm from the spermatheca and accordingly produce males or females. Though this seems to be the case in wasps and the honeybee, no real evidence was found to support such a contention in the case of the bumblebees. In the course of my studies all the first progeny of the queens were found to be females and the males were not produced until the colonies were approaching their "climax" development. In Experiment 11, 1917 (*B. bimaculatus*), it was quite evident that after the male eggs first began to be laid there was a gradual increase in the ratio of their number over those of the female eggs. In Experiment 6, 1919 (*B. impatiens*), after male eggs once began to be laid no more female eggs were laid—at least all eggs producing adults (a very large number) were males. Sladen has also studied colonies that produced all females. In view of the fact that differentiated cells for the reception of male or female eggs have not been found, and that males under normal conditions appear after the majority at least of the female eggs have been laid (in fact may never appear), a voluntary control of the sex of the eggs is an unnecessary explanation. It seems equally logical in the case of the bumblebees to assume that the male eggs begin to

appear at that time in the life of the queen when the store of sperm in the spermatheca becomes diminished, they lose their effectiveness, etc. This would explain why the eggs laid first always produce females (with possible exceptions in the arctic regions where degree of fecundity is probably very low) and that males are usually produced late in the reproductive life of the queen.

Support of the data relating to the fact that queens and workers of the honeybee are produced by feeding is found in the case of bumblebees. Whether the quality of food exerts a controlloing influence upon the production of workers or queens (as is true of the honeybee) was not determined. The fact that the larval stage is much longer in large workers than in small workers and longest in the case of the queen of *Bremus* suggest that quantity alone may account for the differentiation in size. In many ways, the development of the various sized females of *Bremus* represents an intermediate degree of specialization between the honeybee and the more generalized condition found in the solitary bees.

In a paper by Lindhard (1912), a Danish biologist, there is presented the idea that eggs laid by workers must be of some use and that they are fed to larvæ destined to become queens. The basis of this view was that he once saw a queen destroy some worker eggs, one of which after being chewed was laid together with a little pollen on top of a cell of a queen larva. In my colonies where a very close watch was kept of the development of all eggs laid by the queens or workers, I failed to find any evidence to support such an explanation of the origin of the queens. As already mentioned, it is my opinion that the number of egg-laying workers in a normal nest is over-played. If a useful purpose must be attached to the fact that workers lay eggs, we may consider the production of males to fertilize the young queens a useful purpose. If the causes for the laying of male eggs by the queens are as stated elsewhere in this paper, then such a purpose is perhaps not always purely a case of wasted effort. Sladen (1912) has stated that he has had under observation a colony of *B. pratorum* (Linn.) which only produced females. The fact that queens will destroy worker eggs is quite true as will be recorded elsewhere, but these actions find their explanation by other behaviorisms. I do not think, therefore, that the development

of queens is dependent upon malaxated eggs being fed to the larvæ, granting that such a type of cannibalism may occur.

Very few data are available concerning the development of *Psithyrus*. Though no females of *Psithyrus* have been homologized until recently (Plath, 1922) with workers (small females) of bumblebees, there is no reason why a miniature female *Psithyrus* is not the equivalent of a worker *Bremus*. Small females of *Psithyrus* do occur which are as small in proportion to their mother queen as are certain workers of *Bremus* to their mother queen. Plath (1922) figures a series of females of *Psithyrus* which illustrates such a range in size. These small females certainly indicate that they are due to trophogeny. In the field, small *Psithyrus* females are but infrequently encountered and I have never seen them flying around in spring. I have studied, however, pinned specimens of small females of *Psithyrus* which were captured in late spring. What we do know of the habits of *Psithyrus* all indicates that they have a development similar to that of bumblebees (Frison, 1926) and probably that which holds true for the sex determination of *Bremus* holds true to a large extent for *Psithyrus*.

Several facts warrant emphasis in briefly summarizing what has been stated concerning the development of the castes and sexes in bumblebees. The largest females, or queens, are capable of producing both males and females. All adults in my colonies reared from eggs laid by small unfertilized females or workers produced males. Workers are miniature queens, size being the only apparent external modification. A complete transitional series in size of females from the tiniest worker to the queen may exist within the same nest. Considerable evidence was obtained by the study of many colonies of several species of bumblebees that polymorphism of the females is due to trophogeny.

BIBLIOGRAPHY.

Armbruster, L. 1914. Probleme des Hummelstaates. Biol. Centralb., Bd. 34, pp. 685–707, pl. 2.

Bachmann, M. 1915. Biologische Beobactungen an Hummeln. Mitteil. Münch. Ent. Gesellsch., Jahrg. 6, Nu. 9–12, pp. 71–112.

1916. Beobachtungen vor dem Hummelnest. Ent. Zeitschr. Frankfurt a. M., Bd. 29, pp. 89–90, 93–94, 98–99, 103–104; Bd. 30, pp. 1–3.

Coville, F. V. 1890. Notes on Bumblebees. Proc. Ento. Soc. Wash., Vol. 1, No. 4, pp. 197–202.

Friese, H. 1902. Die arktischen Hymenopteren mit Ausschluss der Tenthrediniden. Fauna Arctica., Bd. 2, Lieferung 3, pp. 439–498, Tabel III.

1922. Die europaischen Bienen (Aphidae)—Das Leben und Wirken unserer Blumenwespen. Berlin und Leipzig, Walter de Guyter & Co., 1. Lieferung, 456 pp,. 33 pls.

Frison, T. H. 1919. Report on the Bremidae Collected by the Crocker Land Expedition, 1913–1917. Bull. Amer. Mus. Nat. Hist., Vol. 41, Art. 9, pp. 451–459.

1921. Hymenopterous Insects of the Family Bremidae from the Pribilof Islands, Alaska. Proc. Calif. Acad. Sciences, 4th Ser., Vol. XI, No. 14, pp. 185–187.

1922. Further Biological and Systematic Notes Concerning Bremus kincaidii Ckll. and other Closely Related Species. Ent. News, Vol. 33, No. 7, p. 214–216.

1926. Contribution to the Knowledge of the Interrelations of the Bumblebees of Illinois with their Animate Environment. Ann. Ent. Soc. Amer., Vol. XIX, No. 2, pp. 203–235, pl. XVII.

Hoffer, E. 1881–82. Die Hummeln Steiermarks Lebensgeschichte und Beschreibung Derselben. I Hälfte. Einunddreissigster Jahresbericht der Steirmärkischen Landes-Oberrealschule in Graz., pp. 1–92.

Huber, P. 1801. Observations on several species of the Genus Apis, known by the name of Humble-bees, and called Bombinatrices by Linnaeus. Trans. Linn. Soc. London, Vol. 6, pp. 214–298, pls. 25–27.

Lepeletier, de Saint-Fargeau, Amedee. 1836. Histoire Naturelle des Insectes Hymenopteres. Tome 1, pp. 435–475.

Lindhard, E. 1912. Humlebien som Husdyr. Spredte Traek af nogle danske Humlebiarters Biologi. Tidsskr. Landbrugets Planteavl, Vol. 19, pp. 335–352.

Phillips, E. F. 1915. Beekeeping. The Macmillan Company, New York. p. 187.

Plath, O. E. 1922. Notes on Psithyrus, with records of two new American Hosts. Biol. Bull, Vol. XLIII, No. 1, pp. 23–44, pl. 1.

1924. Miscellaneous Biological Observations on Bumblebees. Biol. Bull., Vol. XLVII, No. 2, pp. 65–78, Figs. 1 and 2.

Putnam, F. W. 1865. Notes on the Habits of some Species of Humble Bees. Proc. Essex Inst., Vol. 4, pp. 98–104.

Reaumur, M. de. 1742. Histoire des Bourdons Velus, dont les Nids sont de Mousse. Memoires pour Servir a l'Histoire des Insects. Premier Memoire, Tome 4, pp. 1–38.

Schmiedeknecht, O. 1878. Monographie der in Thüringen vorkommenden Arten der Hymenopterengattung Bombus. Jenaische Zeitschr. Naturwi., Bd. 12, pp. 303–430.

Sladen, F. W. L. 1912. The Humblebee. Macmillan & Co., London. pp. 283.

Wagner, W. 1907. Psycho-biologische Untersuchungen an Hummeln mit Bezugnahme auf die Frage der Beselligkeit im Tierreiche. Zoologica, Bd. 19, Heft. 46, pp. 1–239, pl. 1, 136 figs.

Wheeler, W. M. 1922. Social Life Among Insects. Lowell Lectures. Scientific Monthly, Vol. 15, Nos. 3 and 4, p. 335.

EXPLANATION OF PLATES.

PLATE IX.

Fig. 1. Adults of *Bremus impatiens* showing variation in the size of females and males.

Fig. 2. Adults of *Bremus bimaculatus* showing variation in the size of females and males.

PLATE X.

Fig. 3. Adults of *Bremus vagans* showing variation in the size of females and males.

Fig. 4. Adults of *Bremus americanorum* showing variation in the size of females and males.

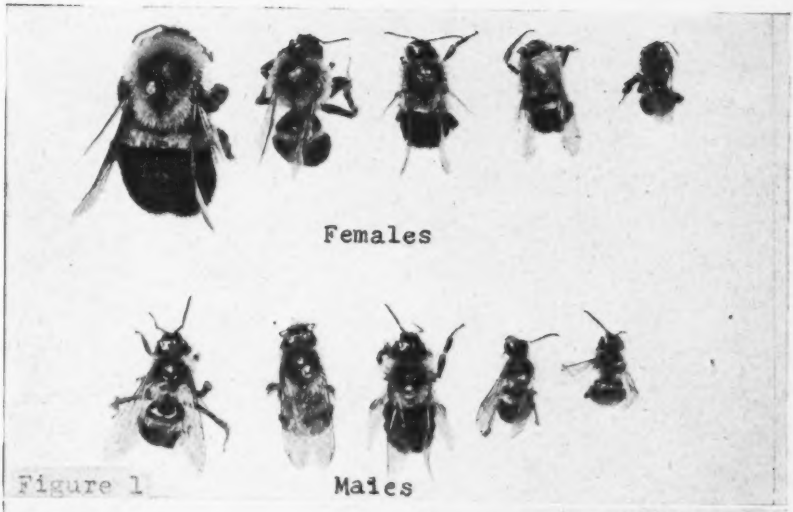


Figure 1

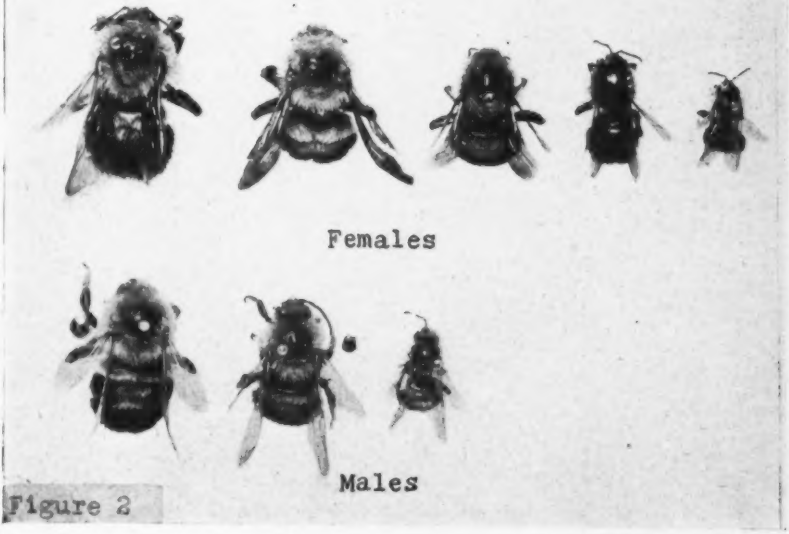


Figure 2

Theodore H. Frison

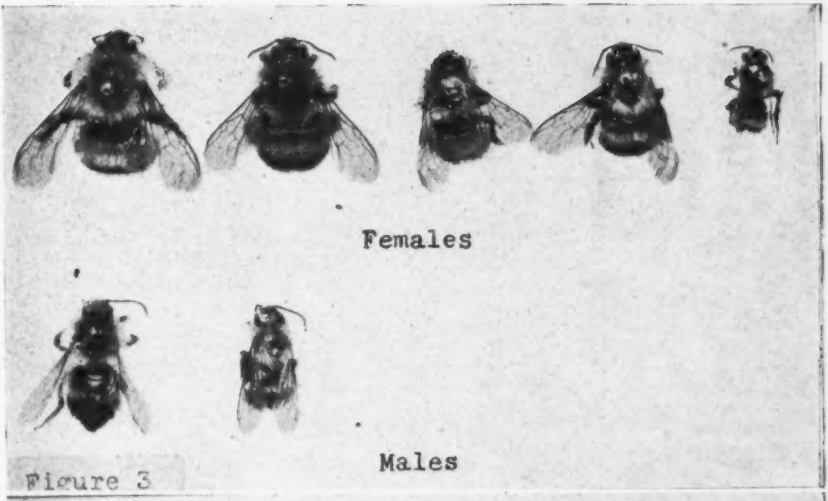


Figure 3

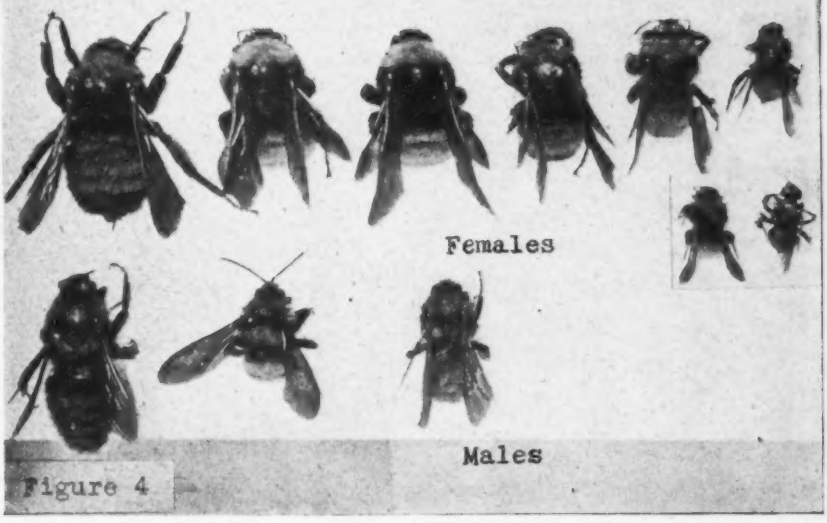


Figure 4

NOTES ON THE HIBERNATION OF SEVERAL NORTH AMERICAN BUMBLEBEES.*

O. E. Plath,
Department of Biology, Boston University.

Although our knowledge concerning the life-history and habits of the various species of bumblebees which inhabit the arctic regions and the Tropics is rather meager, it seems to be definitely established that the colonies of at least some of the tropical species are perennial (cf. von Ihering, 1903), while those of arctic species probably last only a month or two (cf. Friese und von Wagner, 1912, and Frison, 1919). In fact it has been suggested by Sparre-Schneider (1909) that some of the arctic species, *e. g. Bremus hyperboreus* and *Bremus kirbyellus* are solitary in certain parts of the far north. This hypothesis, though interesting, still lacks confirmation.

In the Temperate Zone we have conditions which are more or less intermediate between these two extremes. In the milder parts of the Temperate Zone, such as Corsica, Sardinia, and New Zealand, bumblebees may be seen on the wing throughout the year,† but their colonies, although persisting during the greater part of the year, are probably not perennial. Similar conditions no doubt obtain in certain parts of the United States, *e. g.* the warmer regions of the South and the sheltered rim of the Pacific Coast. However, in the colder parts of the Temperate Zone, such as New England and Central Europe, we have conditions which more closely approximate those of the Arctic, the only difference being a somewhat longer period of activity during the summer. Here in the vicinity of Boston, this period of activity usually ranges from three to six months (about April 15 to October 15), depending on climatic conditions and upon the species. During the remaining six to nine months, the young queens—the only caste which survives our rigorous winters—go into hibernation. Sladen (1912), the foremost English authority on the biology of bumblebees, has the following to say concerning the manner in which the young

*Contributions from the Entomological Laboratory of the Bussey Institution, Harvard University. No. 281.

†Cf. Ferton (1901), Krausse (1910), Hopkins (1914), and Hudson (1918).

queens of some of the European species spend this protracted period of inactivity.

"Immediately after fertilisation the queen seeks a bed in which to take her long winter sleep. The queens of some of the species hibernate under the ground, others creep into moss, thatch, or heaps of rubbish. I have found *B. lapidarius* and *B. terrestris* and occasionally *B. ruderatus* and *B. latreillellus* in the ground, *B. lucorum* and *B. hortorum* in moss, and *B. pratorum* sometimes in the ground, sometimes in moss.

"My observations have been made chiefly on the underground-hibernating species, *lapidarius* and *terrestris*. Both species pass the winter in much the same situations, but *terrestris* likes best to burrow in ground under trees, while *lapidarius* prefers a more open position, almost invariably choosing the upper part of a bank or slope facing north or north-west, though generally near trees.

"In such banks I have sometimes found great numbers of queens, chiefly *lapidarius*, and it is easy to discover them, because in burrowing into the ground each queen throws up a little heap of fine earth, which remains to mark the spot until the rains of autum wash it away. The burrows are only one to three inches long, and if the bank is steep they run almost horizontally. They are filled with the loose earth that the queen has excavated. The queen occupies a spherical cavity having a diameter of about 1⅛ inch.

"It is evidently damp and not cold that the queens try to avoid. Indeed, the northern aspect shows that they prefer a cold situation, and the reason is easily guessed. The sun never shines on northern banks with sufficient strength to warm the ground, so that the queens do not run the risk of being awakened on a sunny day too early in spring, for the queen humble-bee is very susceptible to a rise in temperature in the spring, although heat in autumn, even should it amount to 80° F., will not rouse her when once she has become torpid. The queen easily takes fright while she is excavating her burrow, and I find that many burrows are begun and not finished.

"The queen always fills her honey-sac with honey before she retires to her hibernacle. This store of liquid food is no doubt essential for the preservation of life, and is especially needed, one would think, during September, when the ground is often very dry and warm . . . . . .

"I have dug up the hibernating queens of *Ps. rupestris*, *vestalis*, *barbutellus*, and *campestris* from banks facing northwest, occupying little cavities in the ground, about two inches below the surface, exactly like the queens of *B. lapidarius* and other *Bombi*."

This account of Sladen (pp. 14-16, 72) agrees with that of Hoffer (1882–83, p. 8), except that the last-named author asserts that the young queens prefer a slope facing east for their *hibernaculum*, and that they spend the winter "deep in the bowels of the earth." As will be seen from the following observations, the statements of both of these authors will have to be somewhat modified.

Toward the end of the summer of 1922, some Italian workmen in the Arnold Arboretum showed me a hole in a level, grass-covered spot, where they had seen a number of bumblebees enter. However, it was impossible for me to investigate whether this was the entrance to a bumblebees' nest, until October 15. Unfortunately I lost track of the hole as soon as I began to work, and although I dug down several feet, I was unable to discover any nest, but was rewarded by finding 21 hibernating queens of *Bremus impatiens* in the sod about the hole. All of them were numb, but after being exposed to the comparatively mild air for a few minutes, several took wing.

Having read Sladen's (1912) account concerning the hibernation of *Bremus lapidarius*, I came to the conclusion that these 21 queens had chosen this particular spot in which to spend the winter, because they had found it especially suitable for this purpose. However, the following observations—made since that time—have convinced me that there are other reasons, than those suggested by Sladen (1912), why the young queens of certain species of *Bremus* are found hibernating near each other in large numbers.

On October 2, 1923, I made an unsuccessful attempt to dig up a colony of *Bremus impatiens* in a level, but rather sandy spot in the Arnold Aboretum. Besides several workers which were frantically searching for the entrance to their nest, I discovered 13 young queens of *Bremus impatiens* hibernating several inches below the surface, within a radius of about 2 ft.

This led me to suspect that the young queens of *Bremus impatiens* usually hibernate near the maternal nest, and that the hole about which I had found the 21 hibernating queens

on October 15, 1922, was the entrance to a bumblebees' nest, as was asserted by the workmen who showed it to me. The following observations furnished further proof for this assumption.

On October 6, 1923, I dug up a colony of *Bremus impatiens* in a sandy slope facing south-west. About the entrance to this nest I found over 30 hibernating queens of this species, while the nest itself, in addition to the old queen and several workers and males, contained about a dozen more which had not yet gone into hibernation.

During the past summer I decided to learn more as to how the young queens of *Bremus impatiens* prepare their *hibernaculum*. An excellent opportunity for this investigation was furnished by an exceptionally large colony of *Bremus impatiens* which was discovered in the Arnold Aboretum in August 1926. In the early part of September, young queens could be seen entering and leaving the nest whenever the weather was pleasant. On September 25 and 26, more than 40 young queens were found busily at work digging their *hibernacula* in the sod,* surrounding the nest entrance. Scattered among the little heaps of fresh soil which these young queens were piling up were many others which had been deposited earlier. Near each one of these was a cavity, about ½ inch in diameter. Several of these cavities were examined, and in almost every one a young queen of *Bremus impatiens* was found at a depth of about 2 or 3 inches. The place was again visited on October 1 and 17. By this time most of the little piles of soil had been washed away by rain, and the openings to the *hibernacula* were closed, but on both of these visits several young queens were still busy digging themselves in. On November 11, the piles of soil had disappeared, and no openings could be seen. However, several spades of sod were turned over within a radius of about 4 ft. of the nest entrance, and each of these contained from 2 to 5 hibernating queens of *Bremus impatiens*. These were slowly, but angrily vibrating their wings and protruding their stings, near the tip of which could be seen a small droplet of venom.

Being interested to know at what depth, and in what state, I would find the queens in the middle of winter, I pried loose

*Réaumur (1742) apparently made similar observations, probably on *Bremus lapidarius*, but he seems to have placed them in spring by mistake.

a piece of sod, about nine inches square, near the nest entrance, on February 5, 1927. On this day the minimum temperature was 10° F., and the ground was frozen to a depth of about six inches. The piece of sod was then broken up with a pick to see whether it contained any hibernating queens. Three queens of *Bremus impatiens* were obtained during this operation. Although I dug down about 2 ft., none were found hibernating in the soil below the frozen layer. Of the three queens, No. 1 had been completely crushed by the pick, No. 2 had lost a part of one hind leg, but No. 3 was not injured in any way. Although found imbedded in the frozen ground, these queens had maintained a sufficiently high body temperature to prevent them from freezing solid. Probably as a result of the accident to her leg, queen No. 2 was feebly moving when first noticed, while No. 3 appeared to be dead. During the ten minute walk home, I carried queens No. 2 and No. 3 in the hollow of my hand. When I entered my room, queen No. 3 began to show signs of life by slightly twitching her tarsi. After being exposed to a temperature of about 65° F. for a few minutes, both queens feebly vibrated their wings when disturbed, but did not show their stings. About half an hour later, they began to crawl about, but they refused to eat some honey which was offered to them on that, and on the following day. It is estimated that from two to three hundred queens of *Bremus impatiens* were hibernating in the frozen sod near the place where these three queens were found.

In this connection some observations of Hoffer (1882–83, p. 8) are of interest. About the middle of October 1881, this author dug up a once populous nest of *Bremus lapidarius*, but it contained only some moldy comb and five dead workers. However, in some chewed-up grass in a depression, about 2 ft. from the nest, he found a lethargic queen of *Bremus lapidarius** whose glossy pile indicated that it had been reared during the preceding summer. This author also states that

*About a century ago, Huber (1802), on August 21, took a nest of *Bremus muscorum* in which he found only a few young queens, but he discovered about 35 additional queens in a small cavity, connected with the nest by a narrow passage. From this he concluded that these queens would have hibernated in the cavity, if he had not disturbed them. However, in view of the fact that young queens habitually retreat to such cavities, if available, whenever their nest is disturbed during the summer and fall, this assertion of Huber (pp. 81–82) need not be taken too seriously, especially when one considers that this nest was taken rather early in the season.

he found hibernating *lapidarius* queens "without a trace of grass" in some holes which they had dug themselves, presumably near this same nest, although his account does not make this entirely clear.

From the foregoing observations it is evident that the young queens of *Bremus impatiens*, and probably also those of its close Old World relative, *Bremus lapidarius*, under normal conditions, hibernate in the soil about the entrance to the maternal nest.

I have repeatedly dug in situations, such as Sladen (1912) describes, but only on one occasion have I found a hibernating queen (see below). This fact, and the observations of Hoffer (p. 8), lead me to believe that Sladen (p. 15), like myself in 1922, was unwittingly dealing with a former nesting site, when he found so many young queens of *Bremus lapidarius* hibernating in one place.

It must be pointed out, however, that the habit of the young queens of *Bremus impatiens* to hibernate in the soil about the maternal nest is not a fixed and unalterable instinct. During the past six summers I have transferred over 50 colonies of *Bremus impatiens* to nest-boxes (cf. Plath, 1922a) which were kept in several different situations. Some of these colonies were placed in a third story window of the Bussey Dormitory facing south, others in a window of the second story, facing north, while the remaining colonies were kept on two boards in an abandoned cellar, the boards being about 2 and 6 ft., respectively, from the cellar floor. The higher of the two boards, it may be added, was about on a level with the ground outside the cellar. The soil below the windows of the dormitory, as well as that surrounding the cellar, was covered with sod similar to that in which I have found large numbers of hibernating queens of *Bremus impatiens*, while that in the cellar was barren, and mixed with a considerable quantity of sand. Although hundreds of young queens of *Bremus impatiens*, as well as those of other species, were reared in both of these places, none were found hibernating in the soil nearby.

Having established the fact that, with conditions favorable, the young queens of *Bremus impatiens* hibernate in the soil about the entrance to the maternal nest, I was curious to know whether the young queens of some of our other New England species have the same habit. For this purpose a large colony

of *Bremus affinis*, discovered during the first part of September 1925, was left undisturbed, since many young queens were observed entering and leaving this nest, the tunnel of which entered the ground among some old leaves in a wooded part of the Arnold Aboretum. On November 21, 1925, I dug about the nest entrance, but did not find a single queen. Similar investigations were made in connection with a large colony of *Bremus fervidus* which was discovered during the summer of 1926, the nest being situated in an open, grass-covered slope. On September 25, a number of young queens of *Bremus fervidus* were seen entering and leaving this nest. However, when the deserted nest was dug up on November 11, not a single queen was found hibernating in the sod about the nest, although in both this and the foregoing case, conditions seemed to be ideal for this purpose. While it is not advisable, as a rule, to base definite conclusions on negative evidence, the foregoing observations nevertheless suggest the probability that the young queens of *Bremus affinis* and *Bremus fervidus* do not, under normal conditions, hibernate near the maternal nest, as do those of *Bremus impatiens*.

Bremus affinis belongs to the same group of bumblebees as the European *Bremus terrestris*, and it is stated by Sladen (p. 14) that the young queens of the latter species "like best to burrow in the ground under trees" when seeking a place in which to hibernate. If this is true, it seems probable that the young queens of *Bremus affinis*, and those of other species belonging to the Terrestris group, hibernate in similar situations.

Hibernation of Captive Queens.

The late F. W. L. Sladen (1912) seems to have been the first who attempted to overwinter captive queens. In the fall of 1910, and again in 1911, this author confined some young queens of *Bremus lapidarius*, but none of these experiments proved successful. Better results along this line were obtained by the Danish biologist Lindhard (1912). After failing in his first attempt, this author succeeded in overwintering a number of young *terrestris* and *lapidarius* queens. I should here like to discuss briefly two attempts to overwinter young queens of *Bremus impatiens*.

EXPERIMENT I.

Of the 21 hibernating queens of *Bremus impatiens*, dug up on October 15, 1922, 16 were placed in a box containing about 6 inches of soil. The queens refused to dig themselves in, probably because the conditions were not suitable, and by December 26, all but 4 had died. When disturbed, these 4 queens, numb from cold, began to vibrate their wings very slowly, and although no longer molested, continued to do so for several minutes, as if unable to stop. None of these queens survived the winter.

EXPERIMENT II.

About 30 young queens of *Bremus impatiens* which were found hibernating about the nest taken October 6, 1923, were confined in wire cages from which the bottoms had been removed. These cages were then placed on the north side of a fence, and were lowered about a foot below the surface of the ground to prevent the queens from escaping. By October 14, all the queens had dug themselves in, but apparently only three survived the winter, the first one appearing May 14, 1924, and the other two on May 15.

As stated in the introduction, bumblebees here in the vicinity of Boston are active from about April 15 to October 15. In the following paragraphs I shall briefly record the time, and approximate length, of hibernation of the New England species which occur in this part of Massachusetts, these data being based chiefly upon observations which I have made in the neighborhood of Boston during the past five years. I have also included some valuable notes by Professor O. A. Stevens, of North Dakota Agricultural College, and Mr. F. H. Walker of Salem, Mass.

A. GENUS BREMUS.

Terrestris Group.

I. *Bremus affinis* Cresson (Including its var. *novae-angliae* Bequaert).

Here in the vicinity of Boston the queens of *Bremus affinis* usually begin to leave their winter quarters about the middle of April, but in the exceptionally early spring of 1925, a queen of this species was seen as early as April 7. Mr Walker's earliest record is April 19. In May, the queens are exceedingly abundant, especially on Rhododendron. The young queens are produced chiefly in August and September, the period of hibernation therefore covering about 7 months.

II. *Bremus terricola* Kirby.

Although far less common than the preceding species after about May 1, the queens of *Bremus terricola* are usually more abundant in April. This indicates that the queens of *Bremus terricola* leave their winter quarters somewhat earlier than those of *Bremus affinis*. My earliest record for *Bremus terricola* is April 6, 1925 (on Rhododendron). Most of the young queens are produced during July and August, and hence the period of hibernation is probably somewhat longer than that of *Bremus affinis*.

Borealis Group.

I. *Bremus borealis* Kirby.

Since *Bremus borealis* is extremely rare in this part of New England, it is rather difficult to make any definite statements concerning the habits of this species. I have seen only four living specimens, all of which were queens. The dates are as follows: No. 1, May 29, 1922 (on Diervilla); No. 2, June 6, 1922 (on Rhododendron); No. 3, July 8, 1922 (cf. Plath, 1922b); and No. 4, June 10, 1925 (on Cladrastis and Robinia). The last two queens were heavily laden with pollen, and hence had probably started colonies. These data suggest that the queens of *Bremus borealis*, like those of its close European relative, *Bremus distinguendus* (cf. Hoffer, 1882–83, p. 72) appear rather late in spring. Since in all late-appearing species, the sexual forms are apparently not produced until August and September, it is probable that *Bremus borealis* is no exception to this rule.

Pratorum Group.

I. *Bremus bimaculatus* Cresson.

The queens of this species begin to appear about the same time as those of *Bremus terricola, i. e.* about the middle of April, my first record being April 7, 1925 (on Rhododendron). Like *Bremus pratorum* in Europe, *Bremus bimaculatus* completes its life-cycle very early, most of the young queens being produced in June and July.

While digging up a colony of *Bremus terricola* in a sandy and densely wooded slope facing north, on July 7, 1925, I accidently found a young queen of *Bremus bimaculatus* hibernating in the cool sand, about 6 inches below the surface. Although quite drowsy at first, this queen soon became active and flew away. The young queens of *Bremus bimaculatus* therefore hibernate about 9 months.

II. *Bremus impatiens* Cresson.

Although a queen of this species was seen as early as April 12, 1925 (on Pieris and Erica), the majority do not appear until several weeks later, Mr. Walker's earliest record being May 1. Most of the young queens are produced during August and September, the period of hibernation lasting about 8 months.

III. *Bremus perplexus* Cresson.

My earliest spring record for this comparatively rare New England species is April 12, 1925 (on Rhododendron). As in the case of *Bremus bimaculatus*, the colonies of *Bremus perplexus* apparently break up rather early (cf. Plath, 1927), the young queens hatching chiefly in June and July.

IV. *Bremus ternarius* Say.

Until the spring of 1924, this beautiful species was exceedingly rare in the vicinity of Boston (cf. Plath, 1927). In an earlier paper it was stated that the queens of *Bremus ternarius* "seem to leave their

winter quarters comparatively late in spring" (cf. Plath, 1923). In a letter, dated March 24, 1923, Professor O. A. Stevens makes the following comment on the above statement: "*B. terricola* is one of our common species, and one of the earliest to appear, as you note. With it, or slightly before, comes *B. ternarius.*" Subsequent observations have proved the correctness of Professor Stevens' remarks. On April 5, 1925, Dr. Joseph Bequaert and myself saw a queen of *Bremus ternarius* (on willow), this being my earliest record for any of our New England species. Two days later, four additional queens were seen on the flowers of a Pieris bush. Judging from a large colony taken at Petersham, Mass. on September 15, 1923, most of the young queens are probably produced in August and September. The period of hibernation therefore extends over about 7 months.

V. *Bremus vagans* Smith.

Of the five New England species belonging to the Pratorum group, this is the latest to appear, Mr. Walker's earliest record being April 29, and my own, May 6. The young queens are produced chiefly in August and September, the period of hibernation amounting to about 8 months.

Auricomus Group.

I. *Bremus auricomus* Robertson.

This is one of the New England species which I have been unable to discover in the vicinity of Boston.

Fraternus Group.

I. *Bremus rufocinctus* Cresson.

Like the foregoing, this rare New England species does not seem to occur in this part of Massachusetts.

II. *Bremus separatus* Cresson.

This is one of our less common New England species. My first records are May 13, 1923, and May 13, 1924, both on *Ribes aureum.* Most of the young queens are probably produced in August. In a nest taken on June 23, 1924, and transferred to the Bussey Institution, the first queen hatched as early as July 22, (cf. Plath, 1927). As in the case of *Bremus bimaculatus,* the young queens of *Bremus separatus* therefore hibernate for about 9 months.

Dumoucheli Group.

I. *Bremus americanorum* Fabricius.

In this part of New England, *Bremus americanorum* is even less common than the preceding species, and the queens are among the last to appear in spring, my first record being May 27, 1923. Judging from a colony which I had under observation in that year, the young queens are reared chiefly in August and September, the period of hibernation being about 8 months.

II. *Bremus fervidus* Fabricius.

As in the case of *Bremus americanorum*, the queens of *Bremus fervidus* appear rather late, my first record being May 6, 1923, and that of Mr. Walker, May 26. The young queens are produced largely in August and September. Hibernation therefore extends over a period of about 8 months.

B. GENUS PSITHYRUS.

Ashtoni Group.

I. *Psithyrus ashtoni* Cresson.

The females of this species appear about a month later than those of its hosts, *Bremus affinis* and *Bremus terricola*, my first record being May 6, 1924, and Mr. Walker's, May 21. The young females are produced chiefly in August, but I also have a few records for July and September. The period of hibernation is, therefore, about 9 months.

Fernaldae Group.

I. *Psithyrus fernaldae* (=*tricolor*) Franklin.

Although *Psithyrus fernaldae* is not rare in certain parts of New England (cf. Bequaert and Plath, 1925), I have never taken a specimen in the neighborhood of Boston. The host of *Psithyrus fernaldae* is not known.

Laboriosus Group.

I. *Psithyrus insularis* (=*consultus* Franklin) Smith.

I have never encountered this species, which, according to Franklin (1912), is extremely rare in the eastern part of the United States.

The host of this *Psithyrus*, or at least one of them, is *Bremus flavifrons* Cresson (cf. Sladen, 1915).

II. *Psithyrus laboriosus* Fabricius (Including its variety *citrinus* Smith).

In the vicinity of Boston, this is by far the most common Psithyrus. As in the case of *Psithyrus ashtoni*, the females of *Psithyrus laboriosus* appear about a month later than the queens of their hosts, *Bremus impatiens and Bremus vagans*. Mr. Walker's earliest record for *Psithyrus laboriosus* is May 21, and my own, May 28 (on Vaccinium). The young females, like the young queens of their two hosts, are produced chiefly in August and September. The period of hibernation therefore lasts about 9 months.

Summary and Conclusions.

1. The young queens of *Bremus impatiens*, and probably also those of *Bremus lapidarius*, under normal conditions, hibernate in the soil about the entrance to the maternal nest.

2. As in the case of some of the European species, it is possible to overwinter captive queens of *Bremus impatiens*.

3. *Bremus terricola* and *Bremus affinis*, our New England representatives of the *Terrestris Group*, leave their winter quarters rather early in spring, as do their Old World relatives, *Bremus lucorum* and *Bremus terrestris*.

4. *Bremus borealis* apparently appears rather late in spring, as does its close European relative, *Bremus distinguendus*.

5. *Bremus bimaculatus*, like *Bremus pratorum* in Europe, appears early in spring, and like the latter, completes its life-cycle early in the summer.

6. As in the case of the European Psithyri whose habits have been studied, the females of *Psithyrus ashtoni* and *Psithyrus laboriosus* leave their *hibernacula* about a month later than the queens of their hosts.

LITERATURE CITED.

Bequaert, J. and **Plath, O. E.** 1925. Bull. Mus. Comp. Zool., Vol. 67, pp. 265–288, 2 figs.
Ferton, C. 1901. Ann. Soc. ent. France, Vol. 70, pp. 83–148, pls. 1.
Franklin, H. J. 1912–13. Trans. Am. Ent. Soc., Vol. 38, pp. 177–486, Vol. 38, pp. 73–200, pls. 1–22.
Friese, H. und **Wagner, F. von.** 1912. Zool. Jahrb., Supplement, Vol. 15, 1, pp. 155–210, pls. 5–9, 20 figs.
Frison, T. H. 1919. Bull. Amer. Mus. Nat. Hist., Vol. 41, pp. 451–459, pl. 24, 2 figs.
Hoffer, E. 1882–83. Die Hummeln Steiermarks, Lebensgeschichte und Beschreibung derselben. Leuschner & Lubensky, Graz.
Hopkins, I. 1914. Bull. No. 46 (New Series), New Zealand Department of Agriculture, Industries and Commerce.
Huber, P. 1802. Trans. Linn. Soc. London, Vol. 6, pp. 214–298, pls. 25–27.
Hudson, G. V. 1918. Ent. Monthly Mag., Vol. 54, p. 212.
Ihering, R. von. 1903. Allg. Zeitschr. Ent., Vol. 8, pp. 447–453, 5 figs.
Krausse, A. H. 1910. Ent. Rundschau, Vol. 27, pp. 23–24.
Lindhard, E. 1912. Tidsskr. Landbrugets Planteavl, Vol. 19, pp. 335–352, 4 figs.
Plath, O. E. 1922a. Biol. Bull., Vol. 43, pp. 23–44, pl. 1.
1922b. Psyche, Vol. 29, pp. 189–202.
1923. Biol. Bull., Vol. 45, pp. 325–341.
1927. Psyche, Vol. 34, pp. 122–128, 2 figs.
Reaumur, R. A. de. 1742. Memoires pour servir a l'histoire des insectes. Paris, Vol. 6, pp. 1–30, pls. 1–4.
Sladen, F. W. L. 1912. The Humble-bee, its Life-History and How to Domesticate it. Macmillan & Co., London.
1915. Canad. Ent., Vol. 47, p. 84.
Sparre-Schneider, J. 1909. Tromsö Mus. Aarsh., Vol. 29, pp. 81–160, 1 pl.

THE IMMATURE STAGES AND LARVAL ANATOMY OF ANOMALA KANSANA H. AND McC. (SCARABÆIDÆ, COLEOP.).*

WM. P. HAYES,
University of Illinois.

INTRODUCTION.

During the course of a series of life-history studies of the Scarabæidæ at the Kansas Agricultural Experiment Station, Manhattan, Kansas, an opportunity was presented to assemble a fairly representative series of reared specimens of the immature stages of the common representatives of that family of insects occurring in the region. These have been accumulated with the intention of presenting, sometime in the future, a detailed morphological study which may aid in elucidating characters sufficiently reliable to enable the various larvæ to be recognized without resorting to rearing. Considerable progress along that line has been made which ultimately may produce the results desired.

Among the various species whose life-history was worked out† was a species of Anomala pronounced by specialists as new and described by Hayes and McColloch‡ as *Anomala kansana* (Fig. 30). The immature stages of any insects are always of interest and in the past have been too frequently neglected by entomologists. Moreover, the close affinity of *A. kansana*, with the recently introduced oriental species of the same genus, *Anomala orientalis* W., which occurs in New England, and its not far distant relationship with the Green Japanese Beetle, *Popillia japonica* Newm, make it apparent that such a study as presented herein may be of some value in connection with these important immigrants. On the other hand several native species of Anomala, namely, *binotata*, *flavipennis* and *innuba* cause serious damage at times to such crops as fruit and grains.

---

*Contribution No. 113 from the Entomological Laboratories of the University of Illinois.

†Hayes, Wm. P. and McColloch, J. W., The Biology of *Anomala kansana* (Scarabæidæ, Coleop.). *In* Journ. Econ. Ent. Vol. 17, pp. 589–594, 1925.

‡Hayes, Wm. P., and McColloch, J. W., A New Species of Anomala. *In* Ent. News. Vol. 35, pp. 138–140, 1924.

In his study of the larval anatomy of the Green Japanese beetle, *Popillia japonica*, Böving* made a comparative study of the anatomical features of the Popillia larva with that of an undetermined species which he supposed to be *Strigoderma arboricola* Fab. He gives a translation of Schiödte's† characters of scarabæid larvæ and constructs a key to related genera of Popillia. In this key the genus Anomala is separated from Popillia and Strigoderma (?) on the fact that the claws of the last pair of legs in Anomala are abruptly shorter than those of the fore and middle legs, while in the other genera they are equal in length. Use is also made of the minute anatomical arrangement of the surface of the spiracular peritreme or bulla. This character is of doubtful value for a key because of the difficulty of distinguishing the shape of the so-called "holes."

Except for the work of Böving the writer is unaware of any detailed morphological study of any species of North American white grubs. The present anatomical details are based on a study of nearly mature or third instar (Fig. 1) larvæ. The second instar shows little marked differences, except size, from the third instar while the first instar larvæ differ somewhat in the development of the setal pattern, especially on the ventral aspect of the tenth abdominal segment.

The Egg Stage.

The egg (Fig. 26) is laid in the soil and as with other scarabæid eggs it increases in size and differs in shape as embryological development proceeds. At first the egg is elongate oval in form. It gradually changes to a more spherical shape as it gets older. The color varies from a milky-white to a pearly-gray. When freshly laid the eggs are about one millemeter wide and 2.25 millemeters long. One gravid female upon dissection was found to contain 26 full sized eggs and the total number laid probably greatly exceeds this number. During the course of the life-history study of this species it was not observed whether or not the eggs are enclosed by a capsule of surrounding soil which is held together by a secretion of the female as is the case with other species of the family. It no doubt occurs nevertheless.

Egg-laying was observed in 1921 to begin on June 15, in 1922 on June 14 and in 1923 on June 26. The length of the egg stage varied from 9 to 19 days with markedly different averages for the four seasons

*Böving, A. G., The Larva of *Popillia japonica* Newman, and a Closely Related Undetermined Ruteline Larva. A Systematic and Morphological Study. *In* Proc. Ent. Soc. Wash., Vol. 23, pp. 51-62, 2 pl. 1921.

†Schiödte, J. C. De metamorphosi Eleutheratorum observations. *In* Naturhist. Tidsskrift, series 3, vol. 9, pp. 227-236, pl. VIII-XIX. 1874.

observed. In 1920 the range of the egg stage for 5 eggs observed was from 13 to 15 days with an average of 14.6 days. In 1921 for 486 eggs the range was from 9 to 19 days with an average of 12.6 days. In 1922 for 40 eggs the range was from 9 to 16 days with an average of 13.9 days and in 1923 for 101 eggs from 9 to 17 days with an average of 11.9 days. A summary of the above figures shows a total of 632 eggs under observation with greatest extremes of 9 and 19 days and an average for the 632 eggs of 12.2 days.

The Larval Stage.

The larvæ of *Anomala kansana* closely resemble the larvæ of other species of the genus and possess much in common with other grubs of the family Scarabæidæ. Upon hatching the first instar larvæ (Fig. 27) are about four millemeters long or about twice the length of the egg. The head is about 1.25 mm. wide and the thorax 1.5 mm. wide. When ready to moult to the second instar, the first instar larvæ have increased in length to 13 mm., the head is 1.5 mm. wide, only a slight increase in width, and the thorax is 2.5 mm. wide. The second instar (Fig. 28) individuals vary in size. Soon after moulting they are about 13 mm. long. The head is 2.5 mm. wide and the thorax 3 mm. wide. The last or third instar grubs when nearly mature vary from 20 to 24 mm. in length. The head is 3.75 mm. wide and the thorax at its greatest width is approximately 6 mm. wide. The head is tan colored and the body creamy-white in color.

The total length of the larval stage, including the prepupal stage was noted for 23 individuals and found to average 336.3 days with a minimum of 322 days and a maximum period of 345 days. The first molt occurred from 12 to 36 days after hatching while the second molt varied from four to 53 days after the first molt. The following table (Table I) taken from the work of Hayes and McColloch (loc. cit.) summarizes the length of the various periods of the larval stage.

Table I.

The Length of the Larval Stage of *Anomala kansana*.

Period	Number of Individuals	Maximum Days	Minimum Days	Average Days
Hatching to first molt.....	69	36	12	20.5
First molt to second.....	46	53	4	16.8
Second molt to prepupa.....	20	308	280	298.3
Second molt to pupa.....	21	311	285	301.6
Prepupa to pupa.....	105	16	2	4.06
Total larval stage.....	23	345	322	336.3

Anatomy of Third Instar Larva.

HEAD.

Cephalic Aspect: The cephalic aspect of the head (Fig. 6) capsule, if the clypeus and labrum is excluded, is nearly hemispherical in outline, light tan in color, and is divided by the inverted Y-shaped *epicranial suture* (es) into three regions. The stem of the Y has, about mid-way between the branches and the occiput, a widened, slit-like invagination caused by an infolding of the head capsule forming a lamella for the attachment of muscles. Schiödte describes the epicranial suture as having raised margins in *Euchlora frischii* (Anomala) but it is not so in this species. The area on each side of the stem and branches of the epicranial suture is the divided *vertex* (v) (*parietials* of Crampton), while the area enclosed by the arms is the *frons* or *front* (f). The surface of the vertex is comparatively smooth and bears a few scattered setæ which become more numerous and somewhat longer on the ventro-lateral angles. The five-segmented *antennæ* (ant. and Fig. 8) arise from a bulb-like protuberance of the ventro-lateral angles of the head capsule. The first antennal segment is about as broad as it is long, the second is about twice as long as broad, while the third is greatly elongated being nearly three times as long as the second. The fourth segment is about one-half the length of the third and slightly longer than the fifth which is more ovate and tapering to a point on its distal end. The fourth segment has a small sensory pit near its point of attachment to the fifth segment while the fifth has at least two well marked sense pits (Fig. 8. sp). Immediately below the point of attachment of the antenna and between the bases of the mandibles is a narrowly, triangular membranous area (mn) probably homologous with the *mandibularia* (basimandibula, trochantin of the mandible). A *precoila* (pcl) for the articulation of the mandible is located at the cephalic angle of the membranous mandibularia. It is in the form of a prominent condyle. Near the precoila is a darkened and somewhat invaginated area, the *pretentorina*. This is the external mark of the prententorium (anterior arms of the tentorium). Between the two pretentorina is a transverse suture connecting the two points. This is the *fronto-clypeal suture* (fcs) which separates the area of the front from the clypeus which is quadrilateral in shape and strongly transverse. The *clypeus* is composed of two transverse divisions, the *preclypeus* (pc) which is somewhat membranous in character and the *postclypeus* (psc) which is more strongly chitinized. Their division is indicated in figure 6 by the dotted line. Attached to the ventral margin of the preclypeus is the *labrum*, (l) which is strongly asymmetrical, and because of its rugose surface the ventral margin appears somewhat strongly crenate. A distal aspect of the labrum showing the setæ and rugose surface is shown in figure 23.

The lateral aspect of the head: The right lateral aspect of the head capsule with the mouthparts removed is shown in figure 5. The *front* (f) is apparent in this view and behind it the *vertex* (v) and *gena* (g) are seen

to be fused. No eyes are present and beneath the base of the antenna (ant) which is partially removed, is the membranous articulation of the mandible. Behind or caudad of the vertex and gena is a narrowly triangular area which is divided into a dorsal and ventral region by a transverse *occipito-postgenal suture* (opg). The dorsal, narrowly triangular area is the *occiput* (oc) while the ventral, subquadrangular region is the *postgena* (pg). Immediately behind the postgena and occiput is an area (mla) comparable to the *maxillaria* or *maxillary pleurite*, which folds over the caudal region of the head and generally obscures the occiput and upper part of the postgena. The *clypeus* with its two divisions, the *preclypeus* (pc) and the *postclypeus* (psc) also appear in this aspect as does also the *labrum* (l).

THE MOUTHPARTS.

The mouthparts are shown in relation to each other in figure 7. Since the head is of the hypognathus type the labrum which has already been described lies cephalad of the mandibles. This view shows the maxillary scraper (ms) consisting of a series of six curved teeth which lie in opposition to the file-like stridulating apparatus of the mandible. Neither the labium nor the labial palpus are seen in this aspect because of their being obscured by the maxillæ.

The Epipharynx: The *epipharynx* (Fig. 13), consisting, as in many other insects, of a group of strong setæ, is located on the caudal or inner aspect of the labrum. As pointed out the labrum is asymmetrical and at its distal end is an irregular emargination slightly to one side of the meson. Directly behind this notch on the inner surface is a small raised protuberance which bears four rather strong spines in addition to smaller setæ. Behind these spines the setæ are arranged in a somewhat irregular oval with a smooth area bearing no setæ within the oval. The setæ of the oval are directed toward the mesal plane. On the inner aspect of the *clypeo-labral* suture are two strongly chitinized tormæ (t). One on the right side is very regular and extends almost to the meson. Immediately behind the mesal point of this torma are some rather blunt spine-like chitinous projections which probably are a part of the epipharynx. The torma on the left is more curved and extends mesocephalad not quite reaching the mesal plane.

The ental surface of the clypeus, does not enter much into the makeup of the epipharynx having only a few setæ near its cephalic margin. In certain preparations the caudal margin of the clypeus can be seen to be elongated into two processes which continue ventrad to join the hypopharynx, (hc).

The Mandibles: The two *mandibles* (Figs. 11, 12, 14, 15) are unlike in shape and of a black and tan color. From the cephalic aspect the left mandible (Fig. 11) is seen to be stouter than the right mandible (Fig. 12). They each consist of a grinding or *molar* area (mo) and a cutting or *scissorial area* (sc) which bears, near the distal end, a small notch producing a slight *dentes* (dt). The molar area of the left mandible is somewhat subquadrate while that of the right is slightly concave

with a rim of grinding teeth. Behind the molar area is a thinly chitinous setaceous area the *acia* (ac). These appear to arise on the ventral aspect from where it can be observed that the right acia is long and pointed while the left one is shorter and more rounded. On the dorsal aspect can be seen the *acetabulum* or *preartis* (pa) by which the mandible articulates with the condyle or precoila at the ends of the fronto-clypeal suture. An enlarged sketch of this articulation is shown in figure 17, in which the preartis is seen to articulate with a condylar *precoila* (pcl). The lateral aspect of each mandible presents a flattened surface or *scrobe* (sc) bearing a few setæ. Dotted lines in the drawing of the mandibles mark the areas of pigmentation.

The caudal aspects of the mandibles (Figs. 14 and 15) present the notched aspect of the *scissorial area* (sc) in much the same manner as the cephalic aspect but possess in addition a transversely, *striated area* (sa) arranged in the form of an oval. This is part of a so-called stridulating apparatus which occurs in a number of scarabæid larva and has been described by Schiödte (loc. cit.) and others. Opposed to this series of transverse striations on the maxillæ is a variable number of stridulating teeth (Fig. 21, 24, and 25, st) which will be described in connection with the maxillæ.

On the caudal aspect of the molar area can be noted the *acia* (ac) described above and in addition on the right mandible (Fig. 14) is a some-what rounded, lobe-like structure (x) which is apparently absent on the opposite mandible and which overlaps the hypopharynx when the mandible is closed. This lobe plays an important role in the grinding of food which will be mentioned later in connection with the hypopharynx. This aspect presents a condylar artis, the *postartis* (pta) on each mandible which articulates as seen in figure 7 with an acetabular *postcoila* (ptc) located on the gena. Attached to each mandible but only shown in two sketches (Figs. 11 and 15) are two chitinous processes for the attachment of muscles which have been described as tendons. The mesal tendon has been termed the *rectotendon* (rt) and the lateral one the *extensotendon* (et).

The Maxillæ: The maxillæ (Figs. 20 and 21) present the usual number of parts found in a chewing type of mouthparts except that the galea and lacinia are fused to form the single structure known as the *mala* (m). The *cardo* (cd) articulates with the postgena (Fig. 18) by an articular acetabulum, the *parartis* (pra) which fits into the *paracoila* (prc) located on the postgena. There are two divisions of the cardo into a *subcardo* (sc) which bears the articulation and the *alacardo* (ac) lying between the subcardo and the stipes. The *stipes* (s) is quadrilateral in outline on the caudal aspect, except at its distal end where it is fused to the mala, while on the cephalic aspect it is not separated from the mala. The *palpifer* (pf) is borne on the dorsolateral margin of the stipes. On the mesal margin is a narrowly, elongate sclerite the *parastipes* (ps) or subgalea of many authors. A membrane termed by MacGillivray the *labacoria* (lc) is attached to the inner margin of the cardo, parastipes and stipes. This membrane attaches to the labium and helps close the oral aperture. The *mala* (m) is densely setaceous

and distally bears a series of strong spines. In many larvæ of the copraphagous Scarabæidæ the lacinia and galea are separately distinct and show no traces of fusion. The series of curved teeth-like structures found on the cephalic aspect are six in number on the right maxilla (Fig. 25) while only one was found on the left maxilla (Fig. 24). These teeth point and curve toward the distal extremity of the stipes and lie in apposition to the oval file-like area on the mandible (See Figs. 14 and 15). These stridulation structures, if such they be, have been described by Schiödte* who asserts that the teeth of the maxillæ differ in number and form according to the genera, and further noting that they vary in number from five to twenty, sometimes being straight but more often they are extremely sharp and curved. The ***maxillary palpi*** (mp) are four-segmented. The basal segment is about equal in length to the palpifer and about one-half the length of the second segment. The third segment is about one-half the length of the second while the distal segment is about twice the length of the third.

The Labium: The ***labium*** (Fig. 22) is small and usually concealed. It is partly covered on its lateral margins by the maxillæ. The ***submentum*** (sm) is large and somewhat quadrate. It is bordered laterally by the maxillæ (mx). A small, narrow, transverse area represents the ***mentum*** (mt) which is sharply differentiated from a wider transverse, ***stipula*** (st). Laterally the stipula is prolonged into a deflexed, broadened lobe which is covered by the maxilla. The fused ***glossæ*** and ***paraglossæ*** (lg) or ***ligula*** of some writers is broadly rounded on its distal margin. It is strongly setose and bears a pair of small. two-segmented labial palpi (lp).

The Hypopharynx: The ***hypopharynx*** consists of a densely, setaceous area on the ental aspect of the fused glossæ and paraglosæ and a strongly chitinized area (Fig. 16 and 19) termed by Böving (loc. cit) the hypopharyngeal chitinization (hc). The hypopharnyngeal chitinization is decidedly assymmetrical and somewhat less densely chitinized on the lateral extremities where it is irregularly inflexed to fit snugly against the molar region of the mandibles (Fig. 19) and it is the opinion of the writer that it serves as an accessory organ of mastication. The caudal margin of the chitinized area is continuous with the pharynx, which is probably held open by red-like structures extending dorsally to the epipharynx. In one preparation it was noticed that there is a direct connection between the ental aspect of the clypeus and the hypopharynx. These connecting bands of what appear to be slightly chitinized membranes are shown in figure 13, extending between the clypeus (cl) and the hypopharynx (hc). On the dorsal aspect, near the lateral angles, is a series of small setæ which are similar to the structures described by Carpenter† as the maxillulæ which Crampton asserts are homologous to the crustacean paragnatha.

*Schiödte, G. C. Note sur les organes de stridulation chez les larves des Coleopteres lamellicornes. Ann. Soc. Ent., France. 5th Series. Vol. 4, pp. 39–41. 1874.

†Carpenter, G. H. Mouthparts of some Beetle Larva—. *In* Quarterly Journ. Micro. Soc. Vol. 57, pp. 373–376, 1912.

THE THORAX AND ABDOMEN.

The Thorax: The *thorax* (Fig. 1) consists of the usual three segments each of which bears a pair of jointed legs. The *prothorax* (I) is divided dorsally into three annulets, two of which are much wider than the small posterior one. The division of the two cephalic annulets does not extend far onto the pleuron. A small area of the cervix lying anterior to the three is sometimes apparent, depending on the degree of extension of retraction of the head which causes this segment to appear to be broken up into four annulets. The ventro-lateral angle of the propleuron extends cephalad to partially cover the head-capsule. Near its caudolateral angle is the prothoracic spiracle (Fig. 3) surrounded by a well-defined *peritreme* (p) which is open on its caudal margin in contradistinction to the peritremes on the other segments which are open anteriorly. The peritreme enclose an area known as the *bulla* (b). The prothoracic spiracle is nearly twice as large as the others. No other spiracles are present on the thorax. The prothoracic legs (Fig. 9) are shorter than the others. The *mesothorax* (II) on the dorsum exhibits three larger and more distinct annulets than those of the prothorax. The *metathorax* (III) likewise shows three ring-like divisions dorsally while the following or first abdominal segment shows but two. The metathoracic leg (Fig. 10) is considerably longer than the prothoracic. The elongation occurs in the *femur* (f). The distal end of each leg is provided with a single claw (Fig. 4), and two large setæ. The claws of the metathoracic leg are shorter than those of the other two pairs of legs. Following the interpretation of the parts of the leg (Figs. 9 and 10) as given by Bōving (loc. cit.) in his description of the Japanese Beetle we find a long cylindrical *coxa* (cx) followed by a short *trochanter* (tr). The *femur* (fm) is long and slightly clavate while the next segment (tb) is interpreted as the *tibia* with the tarsus either absent or what is more probable, fused with the tibia since this structure bears the *tarsal claw* (cl and Fig. 4).

The Abdomen: There are eight pairs of spiracles on the abdomen (Fig. 1) on each of the first eight segments. The divisions of the segments are difficult to distinguish because of the annulets and these sometimes are obscured dorsally. From the present study it appears that the first abdominal segment shows but two annulets on the dorsal aspect while segments two to six, inclusive, show three each, segment seven has two while segments eight, nine and ten have but one each. The last or tenth abdominal segment is larger than the others and the anal slit is transverse. The terga and sterna of the abdominal segments are well marked but the pleura are ill-defined.

The Radula: The tenth segment on its dorsal aspect bears roughly three rows of short, stiff, straight setæ. Above these is a much denser cluster of longer setæ which become more numerous on the lateral margins. Ventrad of the anal slit is a group of setæ which occur in two sizes. The longer setæ are roughly arranged in transverse rows and are hooked at the tip. The shorter setæ are arranged in two rows extending

cephalo-caudad along the meson and consist of very short recumbent setæ which point mesad. In some specimens there are ten such setæ in the row on the dextral side of the meson and twelve in the sinstral row (Fig. 2). On the dextral row the setæ are rather uniformly placed while in the sinstral row the spacing is not so uniform. This group of setæ is frequently figured by workers with white grubs. It has no name and as far as is known no function has been suggested for it. In a study of the digging habits of white grubs in observation cages the writer has frequently noticed the grubs making use of this structure to rake off the mouthparts which often become covered with soil as the larva burrows through the soil, especially if it is very wet and sticky. Since the general term "ventral aspect of the last abdominal segment" is cumbersome it is preferable to speak of it as the ***rake*** or ***radula***. The radula does not differ strikingly in the second or third instars but in the first instar is not well developed and some of the spines and setæ are wanting.

The Pupal Stage.

The pupa (Fig. 29) when freshly transformed from the larval stage is creamy white in color. As development proceeds, the darker colors of the adult insect are assumed. The greatest length is about 14 mm. and the greatest width across the thorax and wingpads is about 7 mm. It is not strikingly different from other Scarabæidæ pupæ but does lack the long, pointed, anal processes which occur in Phyllophaga pupæ. On the ventral aspect, the ***front*** (f) is seen to be a large semioval structure lying between the ***compound eyes*** (ce). Immediately behind the front is a somewhat quadrate ***clypeus*** (cl) with only a faint indication of a transverse division into a preclypeus and postclypeus as found in the larva. The ***labrum*** (lb) is caudad of the clypeus and is strongly rounded on its distal margin. Beneath the lateral margins of the labrum can be seen a part of the ***mandibles*** (md) and distad of the mandibles are two segments of the ***maxillary palpi*** (mp). On the mesal margin of the maxillary palpi can be seen the tips of the ***maxilæ*** (mx) and between these lying on the mesal line is the ***labium*** (la).

The tergum of the ***prothorax*** (pt) is noticeable on the ventral aspect lying on each side of the head. Adjoining the lateral margin of the prothorax and extending ventromesad is the ***mesothoracic wing*** (fw) under which lies the ***metathoracic wing*** (hw) only the tips of which are discernible at the distal end of the ***mesothoracic*** wings. Two pairs of legs, the prothoracic (pl) and the mesothoracic (ml) lie mesad of the wings and between these lie the ***thoracic sterna*** (st). The ***metathoracic leg*** (mtl) lies under the wings and only the tip of the tibia (tb) and the five segments of the ***tarsus*** (ts) are exposed beyond the distal end of the wings. Seven distinct abdominal segments (1-7) are evident. The seventh is strongly emarginate on its caudal margin and the developing ***genitalia*** (gt) appear as an oval process lying within the emargination. The pygidial end lying distad of the genitalia and seventh ventral segment bears the ***anal slit*** (al) and is slightly incised on its caudal margin to form two rounded lobes.

Pupation occurs in May, June and early July and varies in length from eight to 20 days. In all, 212 pupæ were observed for the length of the pupal stage. Among the grubs reared from the eggs, the pupal stage averaged 10 days for 16 pupæ. Grubs collected in the field, averaged 12.5 days in 1922 for 153 pupæ observed and in 1923, 44 pupæ had an average period of 9.9 days. These data are summarized in Table II taken from the work of Hayes and McColloch (loc. cit.).

TABLE II.

The Length of the Pupal Stage of *Anomala kansana*.

	Year	Number Reared	Maximum Days	Minimum Days	Average Days
Collected grubs...	1922	153	20	9	12.5
Collected grubs...	1923	43	17	8	9.9
Reared grubs.....	1922	16	12	8	10.

EXPLANATION OF PLATES.

Anomala kansana H. and McC.

Figs. 1, 2, 26, 27, 28, 29, and 30 drawn by Mr. Carl Mohr, others by the author.

PLATE XI

Fig. 1. Nearly mature third instar larva—ant. antenna, as. anal slit, es. epicranial suture, f. front, l. labrum, md. mandible, mp. maxillary palpus, pc. preclypeus, psc. postclypeus, r. radula, Nos. I–III thoracic segments. Nos. 1–10 abdominal segments.

Fig. 2. Ventral aspect of the last two ventral abdominal segments showing the group of spines and setæ on segment ten forming the rake or radula. as. anal slit, r. radula.

Fig. 3. Prothoracic spiracle of the sinstral pleuron. b. bulla, p. peritreme.

Fig. 4. Claw of prothoracic leg. cl. claw, tb. tibia, s. seta.

Fig. 5. Dextral aspect of the head capsule with the mouthparts removed. ant. antenna. two basal segments only, es. epicranial suture, f. front, g. gena, l. labrum, mla, maxillaria or maxillary pleurite, oc. occiput, opg. occipito-postgenal suture, pc. preclypeus, pcl. precoila or mandibular condyle, pg. postgena, prc. paracoila or maxillary articulation, psc. postclypeus, ptc. postcoila or mandibular acetabulum. v. vertex.

Fig. 6. Cephalic aspect of the head and mouthparts. ant. antenna, es. epicranial suture, f. front, fcs. fronto-clypeal suture, l. labrum, md. mandible, pc. preclypeus, pcl. precoila, psc. postclypeus, v. vertex.

Fig. 7. Dextral aspect of the mouthparts *in situ*. The labrum is removed and the labium is concealed by the maxilla. Lettering of the head capsule as in figure 5. cd. cardo, m. maxilla, md. mandible, ms. maxillary scraper, pa. preartis articulating with the condylar precoila (pcl), pta. postartis articulating with the acetabular postcoila (ptc), pra. parartis an articulation of the maxilla at prc.

Fig. 8. Antenna showing sense pits (sp) at distal end.

Fig. 9. Prothoracic leg. cx. coxa, tr. trochanter, fm. femur, tb. tibia, cl. claw.

Fig. 10. Metathoracic leg. Letterings as in figure 9.

PLATE XII

Fig. 11. Cephalic aspect of the sinstral mandible. ac. acia, b. brustia, dt. dentes, et. extensotendon, mo. molar area, sb. scrobe, sc. scissorial area. pa. preartis. rt. rectotendom.

Fig. 12. Cephalic aspect of the dextral mandible, lettering as in figure 11.

Fig. 13. Epipharynx on the ental aspect of the labrum and clypeus with the hypopharynx (hc) showing its attachment to the clypeus (cl). pc. precoila, t. torma.

Fig. 14. Caudal aspect of the dextral mandible showing the stridulating area (sa) ac. acia, dt. dentes, mo. molar area, pta. postartis, sc. scissorial area, x. lobe-like prominence which abuts against the hypopharyngeal chitinization.

Fig. 15. Caudal aspect of the sinistral mandible. Lettering as in figure 14 with the addition of et. extensotendom, and rt. rectotendom.

Fig. 16. The ventral aspect of the hypopharyngeal chitinization (hc). ph. pharynx. The irregular areas on the lateral margins of the hypopharyngeal chitinization shows its adaptation for fitting snugly into the molar area of the mandibles. r.a semi-membranous setaceous area.

Fig. 17. The ball and socket articulation of the mandible in the region of the clypeus. pcl. precoila, pa. preartis.

Fig. 18. The articulation of the maxilla to the postgena (pg). pra. parartis, prc. paracoila.

Fig. 19. Ventral aspect of the hypopharyngeal chitinization (hc) showing its relation to the closed mandibles (md) x, as in figure 14, pta. postartis. At r. the setaceous area shown in figure 16 is covered by the overlapping of the mandible.

Fig. 20. Caudal aspect of the dextral maxilla. ac. alacardo. cd. cardo, lc. labacoria, m. mala, mp. maxillary palpus, pf. palpifer, ps. parastipes or subgalea, pra. parartis, sc. subcardo, s. stipes., Stippled area is membranous.

Fig. 21. Cephalic aspect of the dextral maxilla. Lettering as in figure 20. ms. teeth of maxillary scraper.

Fig. 22. Caudal or ectal aspect of the labium. lg. ligula or fused glossæ and paraglossæ, lp. labial palpus, mt. mentum, mx. membrane and cardo of the maxilla, sm. submentum, st. stipulæ.

Fig. 23. Distal aspect of labrum showing its assymmetry and rugose surface.

Fig. 24. Single tooth of maxillary scraper of the sinstral maxilla.

Fig. 25. Six teeth comprising the maxillary scraper of the dextral maxilla. (see figure 21).

PLATE XIII

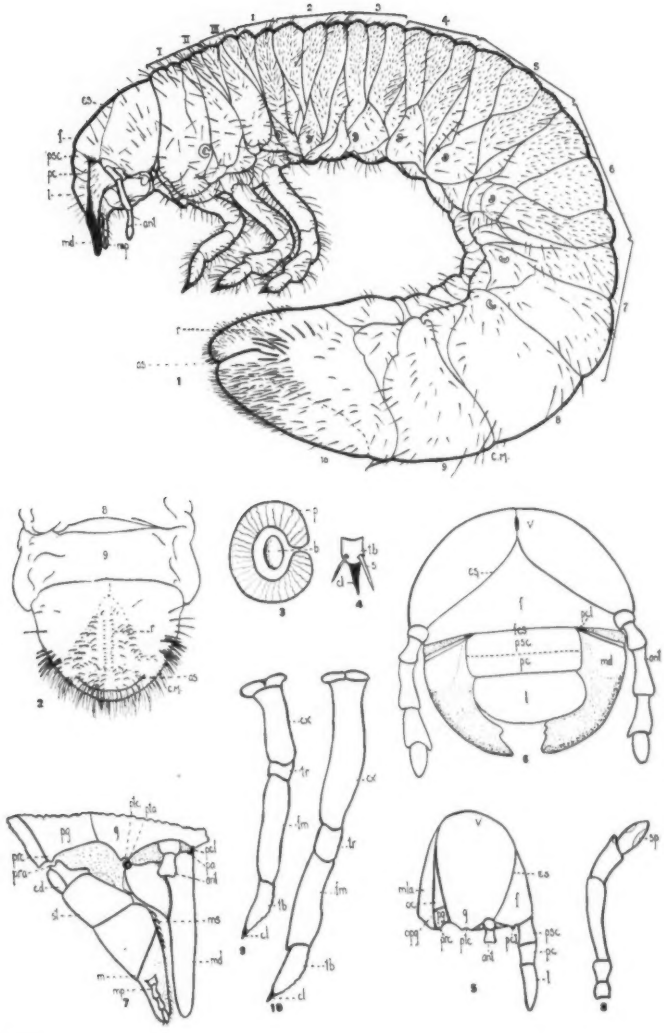
Fig. 26. An egg near the end of embryonic development showing its broadly ovate form.

Fig. 27. A first instar larva soon after hatching. Roman numerals indicate thoracic segments and arabic numerals show the extent and number of annulets of the abdominal segments.

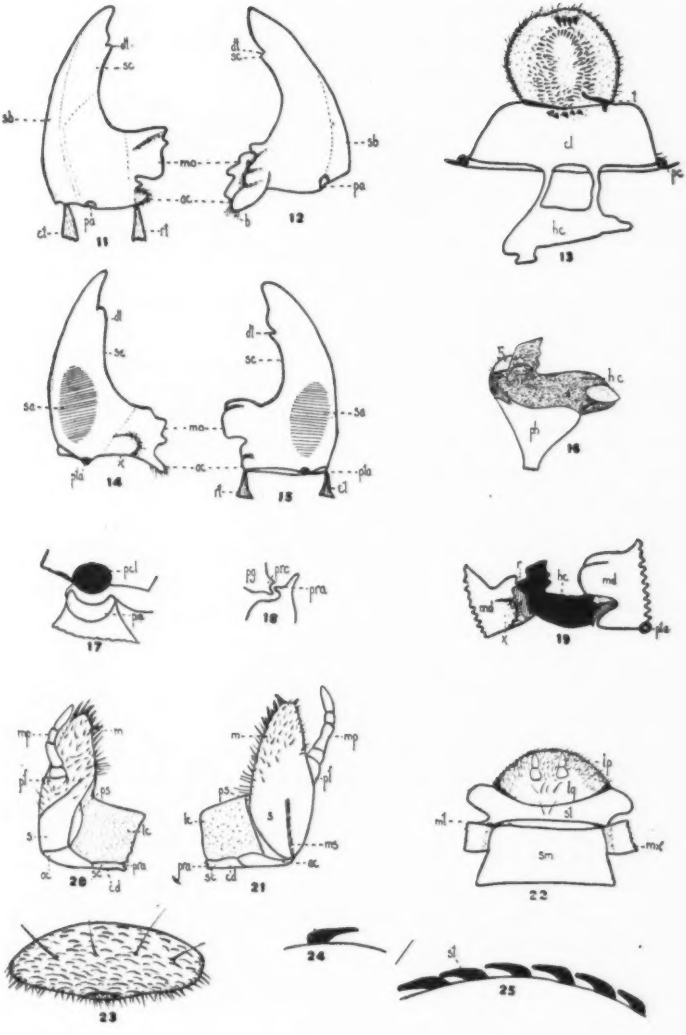
Fig. 28. A second instar larva. Lettering as in figure 1. Numerals as in figure 27.

Fig. 29. Ventral aspect of the pupa, al. anal slit. ant. antenna, ce. compound eye, clp, clypeus. f. front, fw. fore-wing, gt. genetalia, hw. hind wing, lb. labrum, la. labium, md. mandible, ml. mesothoracic leg. mtl, metathoracic leg, mp. maxillary palpus, mx. maxilla, pl. prothoracic leg, pt. prothoracic terga, st. sternum of thorax, tb. tibia, ts. tarsus, Figures 1–7, abdominal sternites.

Fig. 30. Dorsal aspect of adult male *Anomala kansana*.



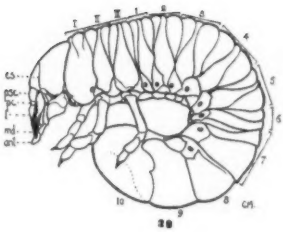
Wm. P. Hayes


dl
sc
sb
mo
ac
pa
cl
pa
rf
b
11
12
1
cl
pc
hc
13
sa
pla
k
pla
14
rf
cl
15
hc
ph
16
pcl
pa
17
pg
prc
pra
18
hc
md
md
k
19
mp
m
pf
ps
s
fc
ac
pra
cd
20
m
mp
pf
ps
fc
s
ms
pra
sc
cd
21
lp
lg
sl
ml
sm
mc
22
23
24
sl
25

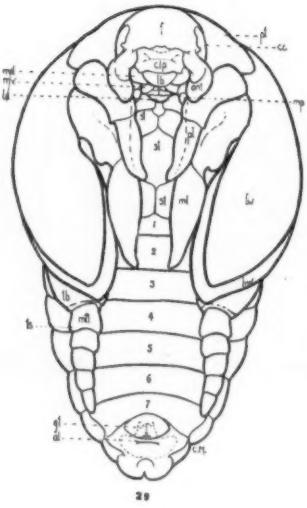
Wm. P. Hayes

28

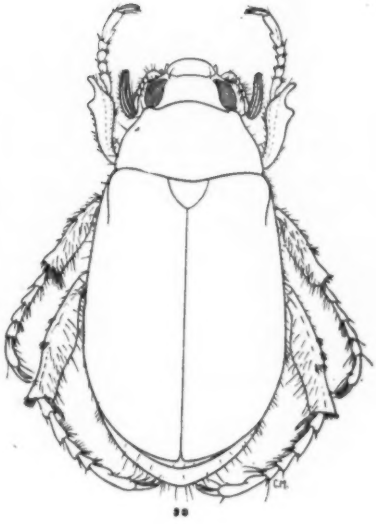
27



26



29



30

Wm. P. Hayes

EXPERIMENTAL DATA ON THE OLFACTORY SENSE OF COLEOPTERA, WITH SPECIAL REFERENCE TO THE NECROPHORI.

C. E. Abbott,
Johns Hopkins University.

Introduction.

When Forel (1908) stated that the olfactory sense of insects was located in the antennæ, his declaration was accepted by the majority of entomologists. More recent discoveries have made it necessary to modify this view. McIndoo (1914, '15, '17, '20) claims that the olfactory sense is located on the bases of the legs and wings. With the exception of one case (1917), McIndoo's morphological studies were supplemented with physiological tests. McIndoo maintains that the removal of antennæ does not obliterate the olfactory sense, but that multilation so disturbs the animal that its responses are not normal. His experimental work is very well done; the greatest objection to it is the artificial set of conditions under which the experiments were made.

Hartwell (1914), accepting McIndoo's dictum concerning the effects of mutilation, tested termites whose antennæ had been treated with cocain hydrochloride and with chloral hydrate. She found that, in a few cases, insects so treated did not respond normally to odors. She was also able to demonstrate the presence of pores on the antennæ. Her results are not complete.

In 1921 von Frisch published the results of some remarkable experiments with bees. His method was to test the responses of bees trained to respond to certain odors, and to test the same individuals after the removal of their antennæ. He found that, in most cases, the bees without antennæ did not recognize the odors. He denies that mutilation, if carefully done, has any lasting effect on the behavior of the insects.

Minnich (1924) conducted experiments on the chemical senses of *Pieris rapæ*. His results seem to indicate that the olfactory sense of these butterflies is located chiefly, but not exclusively, in the antennæ.

My experiments were made with the object of employing conditions as nearly normal as the limitations of the laboratory would permit. The more artifical form of experiment was also used. Efforts were made to determine the most effective methods of eliminating olfactory areas, the possible location of such areas, and the degree of sensitiveness of this sense in the Necrophori.

Material and Methods.

The beetles used in the following experiments were *Necrophorus americanus* (Oliv.), *N. orbicollis* (Say), *N. tomentosus* (Weber), *Silpha inaequalis* (Fab.), and *Trirhabda canadensis* (Kirby). The Necrophori were taken early in June by means of glass jars containing meat buried in the ground to their necks. The beetles were kept in a large wooden box, 17 x 27 inches in extent, and about 10 inches in depth. The box was filled to a depth of 2 inches with clean sand, and was covered with wire screen. The insects were fed decaying flesh; this was also used in some of the experiments. Skatol was also employed experimentally, especially in the determination of olfactory sensitiveness. Test substances were always buried, and tests conducted at night. These precautions were observed in order to eliminate any possibility of the influence of vision in the reactions of the beetles, and also because the Necrophori are chiefly nocturnal.

In the treatment of antennæ three methods were used. In some cases the organs were immersed in cocain hydrochloride (.0032 gms. in 100 c.c. H 2 O) for approximately a minute. The antennæ of other specimens were covered with shellac—or removed entirely. To eliminate the possible olfactory sense of the wing bases, the wings were removed and the points of attachment were covered with shellac. The elytra of the Necrophori and Silphæ were not removed; the small size of *T. canadensis* made the removal of these appendages necessary. It was impossible, of course, to treat the bases of the wings without also covering the bases of the elytra with shellac. To repress possible olfactory senses in the coxæ and trochanters, the bases of the legs were covered with shellac. Various combinations of these methods were also used to prevent stimuli from acting on two or more of the possible olfactory areas.

Although the specimens of *S. inaequalis* were kept in the cage with the Necrophori they were not used in the same experiments. Tests in which these specimens were used were made with individuals. Individual specimens were treated in various ways, and the reactions of these individuals were compared. Some specimens of Necrophorus were also tested in this way.

The experiments with *T. canadensis* were conducted in a somewhat different manner. A number of the insects were kept in a small cage similar to the one used for the Necrophori. The beetles were fed with the leaves of some species of Solidago. Individuals to be tested were removed from the cage and treated to eliminate some possible olfactory organ or organs. The methods of treatment were the same as those employed with the Necrophori. The three substances used in testing the responses of the beetles were the essential oils of clove, bergamot, and almond. A match soaked in one of these substances was brought within a few millimeters of the insect. If no response took place within thirty seconds, the evidence was considered negative. There was no indication that these results were influenced by vision; beetles did not respond to the approach of an unscented object unless actually touched. The usual method was to treat the same organs of ten insects, and to test all of them with the three essential oils. In some cases, however, a few insects succumbed to treatment before the tests could be applied. No attempt was made to keep the individuals distinct. When the experiments were completed, the ten beetles were discarded, and another group was used for the following series of tests. Similar methods were used in testing *S. inaequalis*, excepting that a greater variety of test substances were employed. It was found impractical to test specimens of *T. canadensis* with more than one treated body area, especially when shellac was used. Individuals so treated were visibly affected; many died in a few minutes. Even in the case of beetles with only one set of organs covered, few survived the operation more than two days. Had this altered their responses the results of the experiments might well be questioned, but, as will be pointed out later, such was not the case.

The untreated specimens of *T. canadensis* were all alive and active when released at the end of the period of experimentation. The death of a number of the Necrophori during the

course of the experiments seemed to be due rather to confinement than to mutilation. In fact many Necrophori, both normal and treated specimens, lived until the termination of the period of experimentation. This was about six weeks.

Results.

The nature of the experiments in which the Necrophori were employed makes a certain amount of repetition unavoidable.

On the evening of June 20th the antennæ of four specimens of *N. americanus* and two of *N. orbicollis* were immersed for one minute in a solution of cocain hydrochloride. The antennæ of another specimen of *N. orbicollis* were removed. The insects were marked by cutting off part of one elytron. Five minutes later one treated specimen of *N. americanus* was feeding on a piece of meat. The artificial light drove it away, but fifteen minutes later a treated individual of *N. americanus* was feeding on the meat. A little later it was joined by another treated specimen of the same species.

On June 21st, at 6.30 P. M., the antennæ of three specimens of *N. americanus* were again treated with a solution of cocain. At 8.30 one of them was feeding on the meat. At 9.15 two *N. americanus* and two *N. orbicollis* were similarly treated, and the antennæ of another specimen of *N. orbicollis* were removed. At 10 P. M. one treated specimen of *N. americanus* and two of *N. orbicollis* with no antennæ were feeding on the meat. At 7.15 the antennæ of three specimens of *N. americanus* and two *N. orbicollis* were covered with shellac. A fragment of meat was wrapped in a cloth and buried in the middle of the cage, At this time four beetles were feeding on other pieces of meat scattered about the box. Two were normal specimens of *N. orbicollis;* there was also a specimen of *N. orbicollis* with no antennæ and one of *N. americanus* with antennæ covered with shellac. At 9.50 one specimen of *N. orbicollis* and one of *N. americanus*, both with antennæ covered with shellac, were found on the meat. A specimen of *N. orbicollis* with no antennæ was also feeding.

On June 24th one specimen of *N. americanus* and one of *N. orbicollis*, both treated with shellac, were found on the meat. At 8.25 P. M. the antennæ of two specimens of *N. americanus* and of three specimens of *N. orbicollis* were covered with shellac.

At 10 P. M. all pieces of meat were removed from the cage, with the exception of a large fragment that was buried in the sand. By 10.15 three specimens of *N. americanus* were digging for the meat. Two had antennæ covered with shellac; the third had no antennæ.

At 8.30 P. M. of the 25th, four specimens of *N. americanus* and two of *N. orbicollis* without antennæ were found under the unearthed meat. Three of the specimens of *N. americanus* had treated antennæ. There was also a specimen of *N. orbicollis* with its antennæ covered with shellac, as well as four normal specimens of the same species. At 9.45 P. M. the wings of two specimens of *N. americanus* were removed, and the bases of the legs covered with shellac. Four specimens of *N. orbicollis* were similarly treated. The meat was buried in another part of the cage.

On the 26th, at 7.10 A. M., one specimen of *N. orbicollis* treated on the previous day was found on the meat. At 1 P. M. it was joined by a normal specimen of *N. americanus* and one of *N. orbicollis* with no antennæ.

On the 27th the meat was removed, and a cloth saturated with a .00036 of one percent solution of skatol was buried in the sand. This was done at 1.20 P. M. At 1.45 two beetles were digging for the cloth, and at 2.16 this number had increased to five. One of these was a specimen of *orbicollis* without wings and the leg bases covered with shellac. At 9. P. M. the cloth was removed, and a similar piece, saturated with a .00018 of one percent solution of skatol was buried in another part of the cage. At 9.20 two specimens of *N. americanus* were digging for it; by 9.45 it was unearthed by seven beetles that were trying to eat it. Two were normal specimens of *N. orbicollis*, two were normal specimens of *N. americanus*, two were specimens of *N. orbicollis* without antennæ, and one was a specimen of *N. americanus* without antennæ.

At 6.30 P. M. of the 28th a cloth soaked in a .00009 of one percent solution of skatol was buried in the cage. It was undisturbed on the 29th, and on the morning of the 30th it was removed. At 10 P. M. of the same day a cloth saturated with a skatol solution of the same percentage was buried in the sand. On July 1st, at 9 A. M., it was exposed by a normal specimen of *N. orbicollis* and a specimen of the same species without antennæ. At 5.55 of the same day a cloth saturated

with a .00004 of one percent solution of skatol solution was buried in the box. It was untouched on the morning of July 2nd.

TABLE I.

N. americanus.

Date and Condition of Insect	Test Substance	Response Time	Response
July 3rd Normal	pyridine almond clove skatol	5 seconds 20 seconds 5 seconds	moved away moved away no response moved antennæ
July 3rd No antennæ; no wings	pyridine almond bergamot skatol	10 seconds 15 seconds 15 seconds	moved away moved legs and head no response moved toward
July 3rd No wings; legs treated	pyridine clove almond skatol	immediate 10 seconds	moved away no response no response rubbed antennæ
July 4th No wings; legs treated	pyridine clove almond	immediate 5 seconds 5 seconds	moved away moved away moved away

N. orbicollis.

Date and Condition of Insect	Test Substance	Response Time	Response
No record of date Normal	clove pyridine skatol almond	10 seconds 15 seconds 10 seconds 5 seconds	moved antennæ dug into sand no record moved away
July 4th No antennæ	pyridine clove almond skatol	15 seconds 5 seconds immediate 10 seconds	moved away rubbed mouth moved away chewed stick
July 4th No antennæ no wings; legs treated	pyridine bergamot clove skatol	immediate immediate 43 seconds 30 seconds	moved away moved away moved away moved toward

On July 2nd a cloth soaked in a .00009 of one percent solution of skatol was buried in the box. On the morning of the 3rd it was still untouched.

On July 4th a piece of decaying meat was put into a flower pot, which in turn was placed ten feet above the ground in a tree. On the morning of the 5th a specimen of *N. tomentosus*

TABLE II.

Silpha inaequalis.

Date and Condition of Insect	Test Substance	Response Time	Response
July 10th Normal	pyridine	immediate	moved legs; antennæ
	almond	2 seconds	moved away
	clove	20 seconds	moved away
	isosafrol	15 seconds	moved away
July 11th Normal	almond	immediate	moved away
	pyridine	immediate	moved away
	bergamot	5 seconds	moved away
July 10th No antennæ	pyridine	5 seconds	moved away
	almond	5 seconds	moved away
	clove		no response
	isosafrol		no response
July 11th	almond		no response
	pyridine		no response
	bergamot	no record	moved away
July 10th No antennæ; no wings legs treated	pyridine	10 seconds	moved head; legs
	almond	25 seconds	moved away
	clove		no response
	isosafrol		no response
July 11th No antennæ; no wings; legs treated	almond	10 seconds	moved away
	pyridine		no response
	bergamot	2 seconds	moved away
July 10th No wings; legs treated	pyridine	10 seconds	moved away
	almond	immediate	moved away
	clove	10 seconds	moved away
	isosafrol		no response
July 11th No wings; legs treated	almond	immediate	moved legs; antennæ
	pyridine	5 seconds	moved legs; antennæ
	bergamot	5 seconds	moved legs; antennæ

was found on the meat. On the morning of July 7th the flowerpot was replaced, and a second fragment of meat was placed four feet above ground in a pile of bricks. Near midnight

of the 8th, an aberrant specimen of *N. tomentosus* was taken in the bricks, and a normal specimen was found in the flower-pot on the 9th. Most of the meat used in taking specimens of *N. tomentosus* was nearly fresh.

In the cage was one specimen of *N. americanus* which had no antennæ and no wings, and the leg bases of which were covered with shellac. It invariably found buried meat in a few hours.

TABLE III.

Trirhabda canadensis.

Date and Condition of Insects	Test Substance	Response		Notes
		No. +	No. —	
July 17th Normal	clove	10	0	
	bergamot	9	1	
	almond	10	0	
July 18th No antennæ	clove	8	2	
	bergamot	10	0	
	almond	9	1	
July 19th No wings	clove	10	0	
	bergamot	5	3	8 tested
	almond	8	0	8 tested
July 22nd Legs treated	clove	4	6	
	bergamot	4	4	8 tested
	almond	8	2	
August 3rd Antennæ cocainized	clove	10	0	
	bergamot	9	1	
	almond	9	1	

The accompanying tables represent individual tests in which Necrophori and Silphæ were used.

No attempt has been made to record the exact responses of *Trirhabda canadensis*. Beetles that failed to respond, or that did not respond within thirty seconds were marked negative; those responding within the time indicated were considered positive.

DISCUSSION.

It is evident from these experiments that mutilation does not produce as unreliable results as has often been assumed. In the case of *T. canadensis* particularly, abnormalities produced

by mutilation in no way altered the responses of the insects to chemical stimuli. The similarity of response from beetles differently treated was wholly unexpected. One specimen of *N. americanus* with neither wings nor antennæ remained active and normal to the end of the experiments. Specimens of *T. canadensis* in dying or abnormal conditions responded almost as readily as normal insects.

Anaesthetization is not as effective as mutilation for the elimination of sensation. It is a method which cannot be used on the harder chitinous parts.

In these experiments, the antennæ certainly showed little evidence of being the seat of the olfactory sense. It would be unwise to state that no olfactory organs are located in the antennæ, but that such organs should be restricted to those appendages seems unreasonable. The destruction of the antennal sense, as well as that of the legs and wings, certainly did lengthen the reaction-time in some cases. But, as both the experiments in the cage and with the essential oils proved, it did not wholly exclude odors from the beetles. The attempt to localize the olfactory organs of insects appears to be founded on the fact that in mammals and similar animals such senses are thus localized. Experiment does not indicate that among insects such is the case. It is probable that olfactory organs do occur both in the antennæ and the areas indicated by McIndoo (1915). But it is probable that there is also a more general distribution of the chemical sense over the body of insects. Minnich (1924) seems to have anticipated this conclusion.

The olfactory powers of the Necrophori are certainly remarkable. A specimen of *N. americanus* with neither wings nor antennæ detected and unearthed in half an hour a rag soaked in a .00009 of one percent solution of skatol. All this was done in absolute darkness. Normal specimens of *N. tomentosus* detected meat which was slightly stale and almost certainly placed in situations far from their immediate habitat. Add to this the fact that the Necrophori smell so strongly of putrid flesh that they are positively offensive, and it becomes evident that these insects possess a chemical sense which is almost unique.

The more artificial experiments, including those with *T. canadensis*, corroborated the evidence from the caged Necrophori.

Conclusions.

1. *Necrophorus americanus* and *N. orbicollis* were not greatly affected by mutilation through the removal of wings, antennæ, or by treatment with shellac.

2. *Silpha inaequalis* and *Trirhabda canadensis* were seriously affected by treatment with shellac, but that did not influence their responses to chemical stimuli.

3. Anaesthetization proved to be a fairly reliable experimental method.

4. Removal of wings and the use of shellac on leg bases lengthened the reaction-time of some of the Necrophori and Silphæ.

5. The various methods of treatment did not prevent final responses in the Necrophori.

6. The various methods of treatment did not appreciably alter the reaction-time of *T. canadensis*.

7. Normal specimens of *N. tomentosus* detected comparatively fresh meat at considerable distances,

9. *N. americanus* and *N. orbicollis* responded, even when treated, to skatol in dilutions of .00009 of one percent.

BIBLIOGRAPHY.

Forel, A. 1908. The Senses of Insects, (Trans. McLeod Yearsley), London.

Frisch, K. von. 1921. Uber den Sitz des Geruchsinnes bei Insecten. Zool. Jahr., 53.

Hartwell, Rhoda A. 1924. A Study of the Olfactory Sense of Termites. Ann. Entom. Soc. Am., 27:2.

McIndoo, N. E. 1914. The Olfactory Sense of the Honey Bee. Jour. Exper. Zool., 16.

1915. The Olfactory Sense of Coleoptera. Biol. Bull., 28.

1917. The Olfactory Organs of Lepidoptera. Jour. Morph., 29.

1920. The Olfactory Organs of Orthoptera. Jour. Comp. Neurol., 31.

Minnich, D. E. 1924. The Olfactory Sense of the Cabbage Butterfly Pieris rapae Linn., an Experimental Study. Jour. Exper. Zool., 39.

THREE NEW SPECIES OF PHYTOMYZA.

(Agromyzidæ, Diptera).

S. W. Frost,
Penn. State College.

The following new species are added to those previously described by the writer (1924)* in "A Revision of the North American Species in Phytomyza Fallen." They run in that key as indicated in the accompanying descriptions. The Holotypes have been deposited in the U. S. National Museum.

Phytomyza auricornis n. sp.

A medium size species, 3 to 3½ mm. Front, face, cheeks and antennæ entirely yellow; arista brown; palpi yellow, infuscated at tips, setæ of palpi black; proboscis and setæ yellow; orbits concolorous with front, darkened on upper portion; ocellar triangle subshiny brown, continuous with occiput which is likewise subshiny brown; cheeks about three quarters eye height, yellow of cheeks extending back of eye but intercepted at vertex by brown of the back of the head; front slightly broader than either eye, somewhat produced at the insertion of the antennæ, sides converging below; four pairs of fronto-orbital bristles, the lower pair very short and weak, a sparse row of small setæ on orbits adjacent to eye margin, barely reaching the upper fronto-orbital bristles; a row of small setæ on outer hind edge of head continuing down hind margin of cheek; a single pair of oral vibrissæ, scarcely stronger than the accompanying setæ along the lower margin of the cheek; basal segments of the antennæ entirely yellow, second segment with a dorsal black spine and a weaker ventral spine, third segment yellow, scarcely longer than broad, rounded at tip, covered with short yellow pile, arista 2½ times as long as third antennal segment, brown, microscopically pubescent, thickened on basal third. Mesonotum and scutellum cinerous; four pairs of dorso-central bristles, all about the same size, first and second pairs and third and fourth pairs approximated in their rows, dorso-centrals preceeded by a few small setæ, three or four irregular rows of acrostichals reaching three-quarters of the way to the scutellum, a few small setæ outside the dorso-centrals, four scutellar bristles; sides of mesonotum cinerous, pleural sutures narrowly yellow, 2 presutural, 1 mesopleural, 1 sternopleural and 1 propleural bristle. Abdomen subshiny brown, last segment ♀, shiny black nearly one half as long as the base of the abdomen. Legs brown, knees pale yellow. Wings slightly infumed, rounded at tips, veins pale brown,

*Cornell Memoir No. 78:58–90, 1924. The inclusion of *P. betæ* Coq., at that time was an error. It occurs only in Tasmania, Australia.

vein 1 bends towards the anterior margin of the wing, veins 2 and 3 are subparallel, veins 3 and 4 diverge through their entire course, vein 4 is nearly straight ending slightly beyond the tip of the wing, vein 5 bends gently into the wing margin; second, third and fourth sections of costa as 3–1–1½ or 2; anterior cross vein about one and a half times its length from the division of veins 2 and 3; halteres yellow, calypteres and fringe pale brown.

Holotype ♀, collected by Henry Dietrich, Freeville, N. Y. June 5, 1917. The species runs out at couplet 15, writers key*. It is close to *P. flavicornis* Fall., but the lower fronto-orbitals are weak and there are three or four rows of acrostichals. Food habits unknown.

Phytomyza angelicella n. sp.

A medium size species, 2½ to 3 mm. long. Front and cheeks largely yellow; proboscis and setæ yellow; palpi black; antennal grooves dark brown, oral margin narrowly yellow; cheeks about one half eye height, narrower in front than behind, yellow of cheek continuing back of eye but intercepted at vertex by black of back of the head; orbits concolorous with front but darkened along margins of eyes and especially on upper angles; ocellar triangle subshiny brown continuous with the black of the back of the head, (the so called ocellar triangle is quadrate in shape), back of head subshiny black above, yellow below on outer edges; front somewhat wider than either eye and slightly narrowed below, not at all produced at the insertion of the antennæ; four well developed pairs of fronto-orbital bristles, a fifth weak pair below; an irregular row of small setæ on orbits adjacent to eye margin, extending from the lower fronto-orbital to the vertical bristles tending to form two rows above, some occuring in line with the fronto orbitals (the holotype shows two small setæ on the upper angles of the front), a distinct row of small setæ on the outer margin of the back of the head continuing down the hind margin of the cheek; oral vibrissæ scarcely longer than the accompanying setæ along the lower margin of the cheek; antennæ black, at most the basal segments dark brown, second segment with a dorsal spine, third segment slightly longer than broad, rounded at tip, microscopically pubescent, arista about twice as long as third segment, thickened on the basal third, microscopically but distinctly plumose. Mesonotum and scutellum cinerous, slightly shiny; four pairs of moderately strong dorso-central bristles, first and second pairs approximated in their rows and slightly smaller than the posterior pairs, three or four sparce irregular rows of acrostichals extending about half way to the scutellum, some small setæ in the row with the dorso-centrals, a few scattered setæ outside dorso-centrals, pleural sutures broadly yellow but color not extending on humeral callosities, 1 strong humeral, 1 postalar, 1 supraalar, 1 sternopleural, 1 mesopleural, 2 pre-sutural, and 1 propleural bristle. Abdomen ♂, subshiny brown,

Loc. cit.

somewhat pale yellow on sides of basal segments, male genetalia chiefly shiny brown, centrally divided by a narrow pale yellow line; ♀ similar, genetalia shiny black. Legs brown including tarsi, tips of femur pale yellow. Wings hyaline, rounded at tips, 1st vein yellow slightly beyond humeral cross vein, veins pale brown, costa extending considerably beyond the termination of vein 3, vein 2 bending distinctly towards the anterior margin of the wing then terminating subparallel with vein 3, veins 3 and 4 diverging gently from base of wing to apex, vein 4 nearly straight and ending slightly beyond the tip of the wing, second, third and fourth sections of costa as 3–1–1½, vein 5 bending gently into the margin of the wing, anterior cross vein about 1½ times its length from the division of veins 2 and 3 and distinctly before the termination of vein 1, halteres pale yellow, edge of calypteres and fringe dark brown.

Holotype ♂, reared from *Angelica atropurpurea* by Mr. A. S. Mills at Ithaca, N. Y. He states that the larvæ make linear mines on the upper sides of the leaves. The writer has in addition 9 paratypes; 7 ♂, 2 ♀ from Ithaca, N. Y. This species runs close to *P. albiceps* Meig., (Couplet 39).* It differs chiefly in the presence of a fifth weak fronto-orbital and the abundance of small setæ on the orbits.

Phytomyza marginalis n. sp.

A medium size species, 2½ to 3 mm. long. Front, cheeks and proboscis yellow, palpi black; orbits distinctly darkened or cinerous along the margin of the eye and especially on the upper angles; ocellar triangle cinerous and continuous with the cinerous color of the back of the head; front one and a half times as wide as either eye, slightly longer than broad and protruding slightly at the insertion of the antennæ; antennal grooves darkened, a narrow yellow line on oral margin; cheeks one and a half eye height, slightly narrower in front than behind, somewhat darkened on upper part and yellow color not extending back of eye; four slender pairs of fronto-orbital bristles, sometimes with a weak fifth pair, the lower two pairs approximated in the row, pointing downward and inward, the upper pairs pointing upward; a sparse row of small setæ on orbits adjacent to eye margin, scarcely reaching the upper fronto-orbital; a single row of small setæ on the outer edge of the back of the head; antennæ entirely black, third segment slightly longer than broad and rounded at the tip, sparcely covered with short brown pile, arista twice as long as third segment, subshiny, microscopically pubescent and thickened on the basal third. Mesonotum and scutellum cinerous; four pairs slender dorso-central bristles, first two pairs approximated in the rows, two rows of well developed acrostichals, five to six setæ in a row, several small setæ outside dorso centrals on anterior part of mesonotum; sides of mesonotum cinerous, pleural sutures narrowly yellow; 1 humeral, 1 supraalar, 1 postalar, 1 propleural,

**Loc. cit.*

1 strong mesopleural, 1 sternopleural and 2 presutural bristles. Abdomen subshiny brown, last segment ♀ shiny black lightly dusted and nearly three quarters the length of the base of the abdomen. Legs subshiny brown, knees narrowly pale but scarcely yellow. Wings slightly infumed, costa extending only slightly beyond the termination of vein 3, veins 2 and 3 diverging at base but subparallel on their distal half, veins 3 and 4 distinctly diverging from base to tip, vein 4 straight and ending in the tip of the wing, vein 5 curving gently into the wing margin, second, third and fourth sections of costa as 3–1–2, anterior cross vein about twice its length from the division of veins 2 and 3, and distinctly before the termination of vein 1; halteres pale yellow, calypteres and fringe pale dusky.

Holotype ♀, McLean, N. Y. May 29, 1915, food habits unknown. The writer also has fifteen paratypes; 7 ♀ from McLean, N. Y., 2 ♀ Freeville, N. Y. collected by Henry Dietrich, 4 ♀ and 1 ♂, Ithaca, N. Y. and 2 ♂ McLean, N. Y. Although this species runs to couplet 36 in the writers key*, due to the well developed acrostichals, it is more closely related to *P. chrysanthemi* Kowarz. It differs from *chrysanthemi* however in the presence of four or five fronto-orbitals, well developed acrostichals and the distinctly margined orbits.

Loc. cit.

A NEW SPECIES OF PHYLLOPHAGA FROM MISSISSIPPI.*

J. M. LANGSTON,
A & M College, Miss.

Several years ago while examining specimens of *Phyllophaga* from student collections a few males were found that we were unable to determine. There was one specimen from the 1915 and one from the 1919 collections. During 1923 a few specimens of both sexes were found in student collections. One of these collections was made by Mr. J. Gunby, who lives several miles west of A & M College, Mississippi. This species did not appear in any other collection examined by the writer until the spring of 1926. On April 18, 1926 a number of male specimens were collected about five miles southwest of A & M College by two students, Mr. J. E. Williamson and Mr. H. E. Woodruff. The specimens were seen flying about one hour before dark and captured with an insect net. Later specimens of this species were found in the collections of six other students. This seems to be an undescribed species and a description of it is given below.

Phyllophaga davisi n. sp.†

This species belongs to group XV and runs to the species *affabilis* in Horn's key, with the exception that the inner spurs of the hind tibiæ are not short. The genitalia of the male, however, is not the same as that given for that species by Smith (Proceedings U. S. National Museum, Plate LX, Figure 80).

Body oblong-oval, widest about middle of elytra, color chestnut brown, head slightly darker, some specimens with head and thorax darker, female slightly darker than the male, surface shining. Clypeus concave, margin narrowly reflexed, very slightly emarginate, punctures moderately close in the male, sometimes more sparsely placed at sides, not so close in the female. Front not so densely punctured anteriorly as the clypeus, punctures closer posteriorly than on clypeus or thorax in most specimens. Thorax narrowed in front, widest slightly before

*Contribution from the Mississippi Experiment Station.

†The species is named in honor of Prof. J. J. Davis, Purdue University, La Fayette, Indiana in appreciation of the interest he has taken in the study of the *Phyllophaga* of Mississippi and his willingness at all times to aid in the determination of our species.

the middle, sides curved and slightly sinuate before the hind angles, margin entire and sparsely ciliate, punctures near the anterior margin as closely placed as those on clypeus, more sparsely placed on the remainder of the surface with numerous smooth spaces. There is a vague depressed area near each of the hind angles and in some specimens

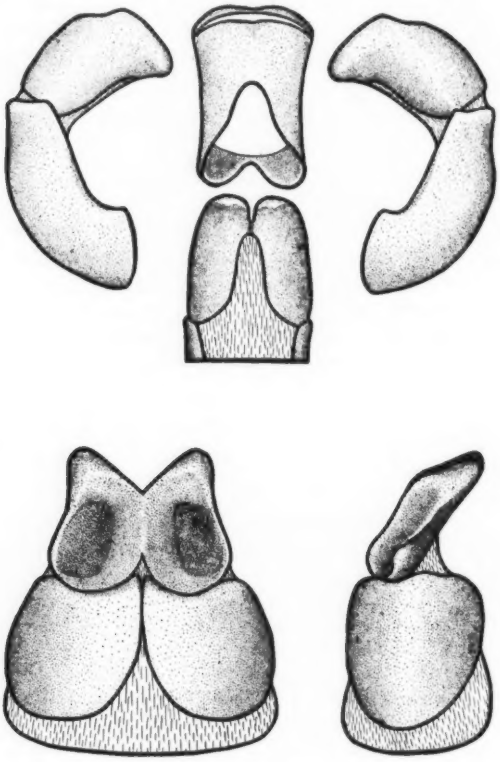


FIGURE 1.

Phyllophaga davisi n. sp. Male and female genitalia both enlarged, the enlargement of the female greater than that of male.

a smaller one on each side about half way between the hind angles and the disk near the posterior margin. Elytral punctures not so well defined but denser than those of thorax, sometimes slightly rugose especially near the umbone; sutural and discal costæ moderately prominent, submarginal prominent on some specimens, others not so prominent; a broad shallow depression on base of elytra between scutellum

and umbone. Pygidium sparsely and indistinctly punctured, moderately shining. Metasternum densely covered with shallow punctures and moderately hairy in the male, less densely and more distinctly punctured and only slightly hairy in the female. Abdomen sparsely and indistinctly punctured. Tarsal claws curved, tooth small and intramedian in the male, larger and median in the female. Last joint of maxillary palpi somewhat oval, the length twice the width, not at all or very slightly impressed. Length 11-12 mm.; width 5.5-6 mm.

Male—Antennæ 9-jointed, club very slightly shorter than the stem. Abdomen not flattened beneath but with a broad shallow depression extending the full width of the last two segments. This depression is limited anteriorly by a faint curved ridge the ends of which extend diagonally about one-half the width of the penultimate segment. Posterior to this line the depression bears numerous irregular elevations on the penultimate segment and a roughened space at middle of the last ventral. Both hind tibial spurs free the inner three-fourths the length of the outer. The genitalia with claspers symetrical and simple. (See Fig. 1.)

Female—Antennæ 9-jointed, club slightly more than one-half the length of the stem. Hind tarsi shorter than those of the male, hind tibial spurs about same length as those of male. Inner three-fourths the length of the outer.

The type series consists of holotype, male, and seven male and two female paratypes.

Habitat—All of our specimens are from student collections and are labeled A & M College, but it is probable that most or all of them were taken several miles west of A & M College, Mississippi in what is known as the flat woods soil area.

MEGALOPSALLUS, A NEW GENUS OF MIRIDÆ WITH FIVE NEW SPECIES FROM NORTH AMERICA (HEMIPTERA).*

HARRY H. KNIGHT,
Ames, Iowa.

Megalopsallus, new genus.

Allied to *Psallus* Fieb., but head larger, broad, shaped much as in *Lygus* Hahn, or *Phytocoris* of the *pinicola* group. Arolia bristle-like, claws broadly curved, without distinct notch at inner side of base, pseudarolia entirely absent. Genitalia much as in *Plagiognathus* Fieb., but right clasper small, little longer than broad; left clasper with small spine at base of dorsal margin which points in a line parallel with margin of genital segment, this clasper having much the same form and holding the tip of the oedaegus as in *Plagiognathus politus* Uhler; genital characters distinctive for the genus. Pubescence composed of closely matted, sericeous, deciduous hairs, and intermixed with more erect and sparsely set, simple pubescent hairs. Rostrum long, reaching the hind coxæ or longer. Tibial spines pale but usually with fuscous dots at base.

Genotype: Megalopsallus atriplicis n. sp.

This genus runs close to *Psallus* in my key (Hemiptera of Connecticut, 1923, p. 429), but differs in the absence of pseudarolia, differently shaped head, and characteristic genitalia.

Megalopsallus atriplicis, new species.

A small pale greenish species, with broad head, long rostrum, clothed with white sericeous pubescence and intermixed with simple fuscous hairs; length 2.5—2.8 mm.

♂. Length 2.5 mm., width 1 mm. Head: width .71 mm., vertex .326 mm. Rostrum, length 1.18 mm., reaching to middle of venter, pale greenish, apex blackish. Antennæ: segment I, length .20 mm.; II, .77 mm., cylindrical, more slender than segment I; III, .62 mm.; IV, .42 mm., pale greenish, last two segments dusky. Pronotum: length .37 mm., width at base .86 mm.

Uniformly pale greenish, eyes reddish brown; femora with numerous small setigerous fuscous dots; tibiæ pale, spines brownish to dusky, each with a fuscous dot at base, becoming obsolete apically, tarsi pale, claws black; membrane whitish, veins concolorous, a distinct fuscous spot at basal angle of larger areole, smaller areole dusky to fuscous, apical half of membrane more or less dusky. Clothed with silvery,

*Contribution from the Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

sericeous pubescence, and intermixed with more erect, fuscous simple pubescent hairs; ventral surface and legs with white simple pubescence. Genital claspers much as in *Psallus seriatus* Reut., but right clasper much reduced, only a little longer than broad.

♀. Length 2.8 mm., width 1.27 mm. Head: width .80 mm., vertex .43 mm. Antennæ: segment I, length .21 mm.; II, .76 mm. Pronotum: length .46 mm., width at base 1 mm. More ovate and robust than the male but very similar in coloration and pubescence.

Holotype: ♂ April 25, 1926, Brownsville, Texas (T. C. Barber); author's collection. *Allotype:* same data as type. *Paratypes:* 14 ♂ ♀, taken with the types on *Atriplex matamorensis* which is the host plant of the species. Texas: 12 ♂ ♀ Feb. 15, 10 ♂ ♀ Sept. 11, 1925, 6 ♂ ♀ Mar. 24, 1926, Brownsville (T. C. Barber), on *Atriplex matamorensis*. 7 ♂ ♀ June 23, 1908, Brownsville (Hart). 3 ♂ Aug. 15, ♀ Sept. 1, 5 ♂ ♀ Sept. 10, 1925, Port Lavaca (R. H. Painter), on *Atriplex arenaria* and *A. matamorensis*. ♂ Aug. 18, 1922, Interior, S. Dak., (H. C. Severin).

Megalopsallus rubropictipes, new species.

Larger but more slender than *atriplicis*, antennal segment II longer, rostrum shorter, sterum fuscous and femora with reddish.

♂. Length 3.4 mm., width 1.24 mm. Head: width .80 mm., vertex .38 mm. Rostrum, length 1.09 mm., only reaching upon hind coxæ. Antennæ: segment I, length .21 mm.; II, .95 mm., cylindrical, a trifle thicker apically, but not attaining thickness of segment I; III, .66 mm.; IV, .43 mm.; greenish yellow, last two segments dusky. Pronotum: length .43 mm., width at base .96 mm.

Pale yellowish, tinged with green, eyes reddish brown; femora with numerous small reddish dots on apical half, a few fuscous setigerous dots also; tibiæ pale, spines yellowish, each with a light fuscous dot at base, tarsi yellowish, tips and claws blackish; sternum fuscous to black, spot at top of coxal cleft and numerous small dots and points on sides of venter, reddish. Membrane and veins whitish, fuscous spot at base of larger areole, darkened smaller areole and dusky on apical half of membrane nearly as in *atriplicis*. Thickly clothed with silvery, sericeous, deciduous pubescence, and intermixed with more sparsely set brownish to dusky simple pubescent hairs. Genital characters nearly as in *atriplicis*, scarcely to be separated on external examination.

Holotype: ♂ Aug. 17, 1925, Florence, Colorado (H. H. Knight), taken at light; author's collection. *Paratypes:* ♂, taken with the type. ♂ ♀ Sept. 12, Trinidad, ♂ Sept. 14, Rocky Ford, ♂ Sept. 15, 1898, Pueblo Colorado (E. D. Ball). The female is too poor for description.

Megalopsallus latifrons, new species.

Allied to *atriplicis* but larger, membrane uniformly whitish, without fuscous spot at base of larger areole, antennal segment II distinctly longer than width of head; greenish to yellowish, femora with small setigerous fuscous dots; length, 3.3—3.5 mm.

♂.Length 3.3 mm., width 1.36 mm. Head: width .89 mm., vertex .37 mm. Rostrum, length 1.38 mm., reaching upon fourth ventral segment, yellowish, apex black. Antennæ: segment I, length .26 mm.; II, 1.03 mm.; III, .74 mm.; IV, .47 mm.; greenish yellow, last two segments becoming dusky. Pronotum: length .54 mm., width at base 1.12 mm.

Uniformly pale greenish, more yellowish on head, mesonotum, body beneath and legs; femora with small setigerous fuscous dots, becoming obsolete on basal half; tibiæ and spines pale yellowish, a small pale fuscous dot at base of each spine. Membrane uniformly whitish, veins pale to yellowish, without fuscous spot at base of larger areole. Clothed with silvery, sericeous pubescence, and intermixed with more erect, fuscous simple pubescence; ventral surface and legs with simple white pubescence. Genital characters very similar to those of *atriplicis*.

♀. Length 3.5 mm., width 1.5 mm. Head: width .87 mm., vertex .47 mm. Antennæ: segment I, length .24 mm.; II, .92 mm.; III, .71 mm.; IV, .36 mm. Pronotum: length .51 mm., width at base 1.18 mm. More robust than the male but very similar in coloration and pubescence.

Holotype: ♂ Aug. 6, 1925, Delhi, Colorado (H. H. Knight); author's collection. *Allotype:* same data as the type. *Paratypes:* 20♂ ♀, taken with the types on the host plant, *Saueda diffusa* Wats. Colorado—♂ Aug. 30, Fort Collins, ♀ July 20, 1898, Delta (E. D. Ball). Mutilated specimens are present from Grand Junction which probably belong here. Texas—♀ Aug. 19, 2♂ Aug. 22, 1925, Port Lavaca (R. H. Painter), collected on *Dondia linearis* which is probably another host for the species. ♀ June 25, 1917, Victoria (H. H. Knight).

Megalopsallus latifrons diversipes, new subspecies.

Suggestive of *latifrons* but differs in the longer second antennal segment which nearly equals width of pronotum at base; femora more or less reddish on apical half, fuscous dots not apparent on hind tibiæ at base of the yellowish spines; the simple fuscous pubescence on the dorsum somewhat heavier than in *latifrons*.

♂. Length 3.4 mm., width 1.3 mm. Head: width .89 mm., vertex .41 mm. Rostrum, length 1.4 mm., reaching upon fifth ventral segment. Antennæ: segment I, length .266 mm.; II, 1.06 mm.; III, .89 mm.; IV, .44 mm. Pronotum: length .50 mm., width at base 1.09 mm.

♀. Length 3.8 mm., width 1.6 mm. Head: width .93 mm., vertex .53 mm. Antennæ: segment I, length .266 mm.; II, 1.23 mm.; III, 1 mm.; IV, .44 mm. Pronotum: length .56 mm., width at base 1.27 mm.

Holotype: ♂ June 14, 1917, Biloxi, Mississippi (H. H. Knight); author's collection. *Allotype:* taken with the type at light. *Paratypes:* 22 ♂ ♀, taken with the types at light. The next morning various plants in the same vicinity were swept with the net but without finding this species.

Megalopsallus brittoni, new species.

Distinguished by the long second antennal segment which in length (♂) exceeds basal width of pronotum; form and color of head, especially the broad vertex and large eyes, very suggestive of a female *Phytocoris* of the *pinicola* group, but size smaller.

♂. Length 4 mm., width 1.5 mm. Head: width .95 mm., vertex .43 mm. Rostrum, length 1.66 mm., scarcely attaining posterior margins of hind coxæ. Antennæ: segment I, length .29 mm.; II, 1.33 mm.; III, 1.03 mm.; IV, .53 mm.; yellowish to dusky, last two segments light fuscous. Pronotum: length .55 mm., width at base 1.23 mm.

General coloration pale yellowish to dusky, pronotum, mesoscutum, scutellum, and thorax beneath more reddish, venter more strongly yellow; femora reddish yellow to dusky red-brown, small setigerous fuscous dots apparent; tibiæ pale to dusky, spines pale without fuscous dots at base. Hemelytra pale yellowish, tinged with dusky, somewhat darker apically, cuneus concolorous with corium; membrane whitish, tinged with brownish, areoles somewhat darker, veins tinged with reddish, anal area dark brown bordering vein. Dorsum clothed with silvery, sericeous pubescence, and intermixed rather abundantly with more erect, fuscous simple pubescence; ventral surface and legs clothed with simple pale pubescence. Genital characters very similar to other members of genus, apparently not exhibiting good specific characters.

Holotype: ♂ July 4, 1904, Westville, Connecticut (W. E. Britton); author's collection.

Megalopsallus adustus, new species.

Allied to *brittoni* but second antennal segment shorter, darker colored, the thorax and femora strongly fuscous.

♂. Length 4.1 mm., width 1.5 mm. Head: width .98 mm., vertex .44 mm. Rostrum, length 1.7 mm., attaining posterior margins of hind coxæ, yellowish brown, apex blackish. Antennæ: segment I, length .28 mm.; II, 1.2 mm.; III, 1 mm.; IV, .53 mm.; dusky yellowish brown, darker apically. Pronotum: length .58 mm., width at base 1.24 mm.

Fuscous over a yellowish ground color, thorax, venter and femora darker, sternum more nearly black; basal area of hemelytra lighter, tip of scutellum pale; membrane fuscous brown, more whitish bordering apex of cuneus and between larger areoles. Legs fuscous brown to darker, femora with small setigerous fuscous dots apparent through the dark ground color; tibiæ pale to dusky, spines yellowish, small darker points apparent at base of spines; tarsi dusky brown, claws black. Dorsum clothed with white to yellowish sericeous pubescence, and intermixed with simple fuscous pubescence; sides of thorax and venter bearing silvery, sericeous pubescence and intermixed with simple yellowish pubescence. Genital characters very similar to those of *brittoni*.

♀. Length 4 mm., width 1.5 mm. Head: width .95 mm., vertex .52 mm. Antennæ: segment I, length .266 mm., II, 1.21 mm.; III, 1.03 mm.; IV, .47 mm. Pronotum: length .58 mm., width at base 1.39 mm. Very similar to the male in coloration and pubescence.

Holotype: ♂ October 8, 1918, Anahuac, Texas (H. S. Barber); U. S. National Museum collection. *Allotype:* ♀, taken with the type. *Paratype:* ♀, taken with the types.

KEY TO SPECIES OF MEGALOPSALLUS.

1. Hemelytra, femora, and frequently the body tinged or darkened with fuscous..5
   Hemelytra pale to greenish, never darkened with fuscous; femora frequently reddish, or bearing setigerous fuscous dots.....2
2. Membrane with distinct fuscous spot on basal angle of larger areole.....3
   Membrane without such fuscous spot.....4
3. Antennal segment II equal to, or only slightly exceeding width of head across eyes, being distinctly shorter than basal width of pronotum; length, 2.5–2.8 mm.....**atriplicis** n. sp.
   Antennal segment II in length distinctly greater than width of head, nearly or quite equal to basal width of pronotum; length, 3.4–3.6 mm. **rubropictipes** n. sp.
4. Femora pale to greenish yellow, apical half with small, setigerous fuscous dots on anterior aspect; antennal segment II distinctly shorter than basal width of pronotum.....**latifrons** n. sp.
   Femora distinctly reddish on apical half; antennal segment II nearly equal to basal width of pronotum.....**diversipes** n. subsp.
5. Antennal segment II of male exceeding basal width of pronotum; hemelytra uniformly tinged with dusky or fuscous, pronotum, scutellum and ventral surface of body lighter, tinged with reddish.....**brittoni** n. sp.
   Antennal segment II of male not equal to basal width of pronotum; apical half of clavus and corium distinctly fuscous, pronotum, scutellum, and ventral surface of body dark fuscous.....**adustus** n. sp.

A NEW RABBIT BRUSH APHID FROM UTAH.

GEORGE F. KNOWLTON,*
Utah Agricultural Experiment Station, Logan.

An interesting aphid was found on rabbit brush (*Chrysothamnus viscidiflorus*) in the mouth of Blacksmith Fork Canyon on July 18, 1925. Large colonies of this shining, yellowish-green aphid were present on the tip three to six inches of the branches. The damage consisted of twisting and stunting the tip ends of the twigs, curling the leaves, and stunting the flower heads and their supporting stems. A black fungus on the honeydew-coated foliage seemed to have no effect on the aphids or their host plant. Many curled bushes from past years were dead, and it is common for badly curled, heavily infested branches, or whole bushes, to succumb in early fall.

Durocapillata gen. nov.

Wing venation typical; antennal tubercles moderately prominent; body and appendages armed with prominent bristly hairs most of which are noticeably enlarged at the tip; cornicles large (except in males) cylindrical with pronounced constriction before prominent flange; cauda conical with one or two globate sensilla in addition to the long, tapering ones. Males and oviparous females apterous.

Sub-family: APHIDINÆ. Type: *Durocapillata utahensis.*

Durocapillata utahensis n. sp.

Migrants numerous by June 15, 1926, and all had disappeared soon after July 18, considerable spread having occurred. Severe curling occurred on bushes upon which aphids overwintered, with less curling of leaves on plants to which aphids had migrated during the season. The apterous viviparæ were numerous for about a month after egg-laying was in progress, present in the large colonies of oviparous females and less numerous males. Eggs were first observed September 20, the apterous oviparæ and males being numerous at this time. Eggs were deposited in great numbers in captivity, cemented to plant, container, or unattached. A few eggs were found under natural conditions on the rabbit brush cemented to the scales at the base of the flower heads or on the twisted leaves.

*The writer wishes to express his appreciation to Dr. C. P. Gillette, Miss M. A. Palmer, and Professor O. W. Oestlund for opinions regarding this aphid, while the writer assumes the responsibility for any errors.

Syrphid larvæ, aphis lions, ladybird beetles and larvæ and a hemipterous predator, assisted in late summer by a hymenopterous parasite, were seldom able to clear up colonies of this rapidly reproducing aphid. Another insect associated with the aphid colonies was a large black ant that attended in small numbers.

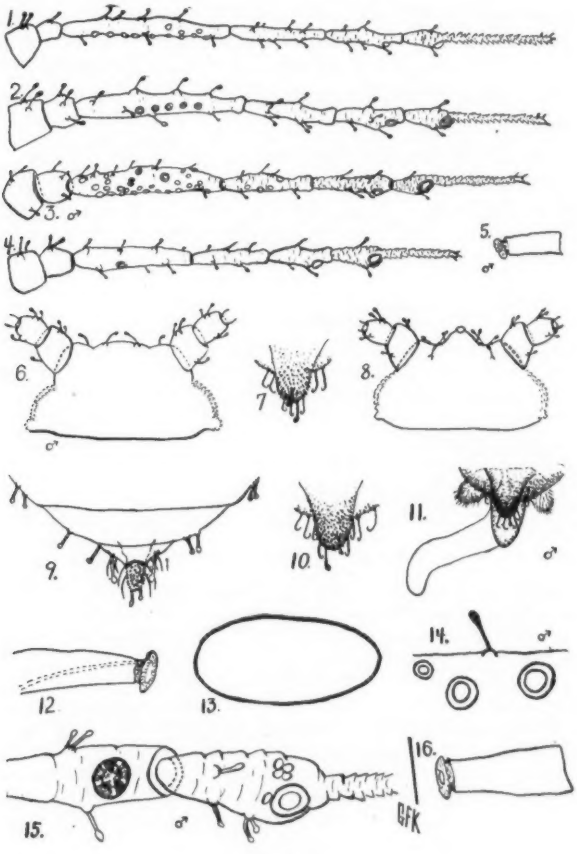


FIGURE I.

1, Antenna of alate viviparous female; 2, antenna of apterous viviparous female; 3, antenna of male; 4, antenna of oviparous female; 5, cornicle of male; 6, head of male; 7, cauda of oviparous female; 8, head of alate female; 9, posterior end of alate female; 10, cauda of apterous female; 11, posterior end of male; 12, cornicle of alate female; 13, egg; 14, portion of male antennal III much enlarged; 15, portion of antennal V and VI of male, much enlarged; 16, cornicle of oviparous female.

Alate vivipara.—Size 2.5 to 2.8 mm. long; sensilla over body and appendages prominent and spinelike, most of which are enlarged at the tip; abdomen rather broad; antennal tubercles moderately prominent; antennæ rather short and black; antennal III, 0.35 to 0.42 mm. with nine to thirteen wide-margined secondary sensoria in irregular row or sometimes rather scattered; IV, 0.21 to 0.25 mm. with 0 to 1 sensorium; V, 0.15 to 0.19 mm.; VI, 0.35 (0.1+0.25) mm.; legs rather short; wing venation not reduced, veins prominent, brownish-black; body yellowish-green and shiny as though moist; lateral tubercles lacking; cornicles large, prominent, 0.33 mm. long, cylindrical, black, with pronounced constriction before broad flange; cauda cone-shaped, with several pointed and two globate sensilla.

Apterous vivipara.—Length 2.2 to 2.8 mm.; width of well-arched abdomen 1.16 mm.; body and appendages armed mostly with spine-like sensilla, usually enlarged at tip; rostrum reaches beyond second coxa; antennal tubercles moderately prominent; antennæ yellowish-green to blackish; segments III, 0.37 mm., with two to six secondary sensoria in a row; IV, 0.25 mm.; V, 0.17 mm.; VI, 0.31 (0.1 + 0.21 mm.); body yellowish-green, shiny, as though moist; cornicles large, 0.41 mm. long, blackish to black, with a pronounced constriction before prominent flange; cauda cone-shaped, elongate, with two globate and several pointed sensilla.

Apterous ovipara.—Similar to apterous vivipara, but with two or three large, light-colored eggs usually showing through the wall of the well-arched abdomen; rostrum long, reaching abdomen; antennal III, 0.27 mm. with one or two sensoria: IV, 0.18 mm.; V, 0.13 mm.; VI, 0.25 (0.08 + 0.17) mm.; cornicles 0.35 mm. long, prominent, blackish but slightly smaller than in the vivipara.

Apterous male.—Length 0.82 to 1 mm., much smaller than the female; rostrum long, reaching abdomen; antennal tubercles moderately prominent; antennæ conspicuous, black; III, 0.3 mm. with seventeen to thirty scattered sensoria; IV, 0.15 mm. with 0 to 3 sensoria; V, 0.13 mm.; VI, 0.26 (0.07 + 0.19) mm.; sensoria with wide margins; hairs over body and appendages prominent and usually enlarged at tip; more active, nervous and awkward appearing than other forms; body reddish-brown to dark red with long legs mostly black; cornicles small, black, cylindrical, 0.13 mm. long with constriction before the flange; cauda conical, with usually only one globate hair at tip, besides long, pointed hairs.

Egg.—0.7 to 0.8 mm. long; whitish-yellow in body and when deposited, but later becoming greenish-yellow, bright green, blackish, and finally shining black. First eggs were observed September 20, 1926. Eggs found free or cemented to scales below flower heads and on twisted leaves.

Cotypes in the collection of the Utah Agricultural Experiment Station and in the U. S. National Museum.

NEW SPECIES OF ACINOPTERUS (HOMOPTERA, CICADELLIDÆ).*

PAUL B. LAWSON,
Lawrence, Kansas.

The material on which this paper is based has been accumulating for several years chiefly through the collecting of Mr. A. A. Nichol in Arizona. This southwestern region seems to be the native land for most of the members of this genus and will doubtless continue to yield new species. The writer is greatly indebted to Mr. Nichol for the fine lot of specimens sent him and wishes also to acknowledge his gratitude to Dr. E. D. Ball for the generous use of material from his collection and also to those in charge of the collections of the United States National Museum for the privilege of studying all the specimens there. Thanks are also due Miss Kathleen Doering for making the drawings.

Since this paper adds so many new species to the genus it has been thought best to present the following new key for the separation of all the species that are now to be included in the genus.

Key to Species.

A. Apex of tegmen strongly acute; costal margin straight clear to tip.
  B. Species more or less distinctly greenish.
    C. Species large, females over 6 mm. long; elytra milky-green. ..*lactus* sp. n.
    CC. Species smaller, females less than 6 mm. long.
      D. Species usually bright green throughout; elytra usually with green veins.....*productus* Lawson
      DD. Species with elytra at least pale green and usually without green veins.
        E. Species distinctly green; vertex angularly produced. ..*arizonanus* sp. n.
        EE. Species but slightly green; vertex more roundingly produced, *productus* var. *albidus* var. n.
  BB. Brownish or grayish species.
    C. More robust species.
      D. Darker colored species.
        E. Male plates long and narrow, parallel-margined, apices rounded; last ventral segment of female without lateral angles, *acuminatus* Van Duzee
        EE. Male plates broader and shorter, apices distinctly divergent; last ventral segment of female with distinct lateral angles, *angulatus* Lawson
      DD. Lighter colored species.
        E. Veins strongly margined with black, giving striking variegated appearance.....*pulchellus* sp. n.

*Contribution from the Department of Entomology, University of Kansas.

EE. Veins not strikingly margined with black.....*pruinosus* sp. n.
CC. More slender species.
D. Front, viewed from side, strongly convex.
E. Yellowish-white species; tip of second anal vein darkened, *inflatus* sp. n.
E. Pale buff species; tip of second anal vein not darkened..*doeringi* sp. n.
DD. Front, viewed from side, straight or but slightly convex.
E. Species not at all or but slightly marked with red.
F. Species usually over 5 mm. long.
G. Vertex strongly and roundingly produced, *productus* var. *fulvus* var. n.
GG. Vertex more angularly or less strongly produced.
H. Pale yellow species; veins with but few faint dark borders, *inornatus* (Baker)
HH. Yellow to brownish species; veins, especially apically, distinctly bordered with brown.
I. Species 5.75 mm. long or over.....*balli* sp. n.
II. Species less than 5.75 mm. long.....*catalinanus* sp. n.
FF. Species usually less than 5 mm. long.....*parvulus* sp. n.
EE. Species strikingly suffused with red.....*aridellus* Osborn
AA. Apex of tegmen rounded; costal margin not running straight clear to tip.
B. Species brownish or grayish, not distinctly green.
C. Robust species.
D. Species large; last ventral segment of female strongly produced medially.....*brunneus* Ball
DD. Species smaller; last ventral segment of female normally produced.
E. Species with elytra but slightly variegated.
F. Very robust species, less than 5.5 mm. long.....*latus* sp. n.
FF. Less robust species; 5.5 mm. or longer.....*pallidus* Lawson
EE. Species with elytra distinctly variegated...*viridis* var. *variegatus* Ball
CC. Rather elongate species.
D. Over 5 mm. long; elytra quite long.....*elongatus* sp. n.
DD. Less than 5 mm. long; elytra distinctly shorter.
E. Almost uniformly brownish; plates of male distinctly pointed and diverging apically.....*rileyi* sp. n.
EE. Greenish-yellow, elytra marked with brown; plates of male more rounded and less divergent apically.....*bakeri* sp. n.
BB. Greenish species.
C. Species larger; plates of male tapering and distinctly divergent apically.....*viridis* Ball
CC. Species smaller; plates of male parallel-margined and but slightly divergent apically.....*obtutus* Lawson

Acinopterus lactus sp. n.

The largest of the greenish species. Close to *productus* but larger. Length of female 6–6.25 mm.

Vertex half longer at middle than next the eye, not quite twice as wide as long, without transverse depression. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra with acutely pointed apices and with five or six cross-veins between first and second anal veins. Last ventral segment of female characteristic of genus, the lateral margins rounding to slightly notched and produced posterior margin. Pygofer bearing a few short spines and slightly exceeded by ovipositor.

Color: Pale green above and below except for brown eyes. Elytra diffused with milky-white, with few dark spots apically. Wings smoky apically. Underside pale to bright green.

Holotype, female, Sierrita Mts., Arizona, 3000–4000 ft. *Paratype*, female, Tempe, Arizona. Both types taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus arizonanus sp. n.

A greenish species close to *lactus* but smaller and with more sharply pointed vertex. Length of female 5.6 mm.; length of male 5.4 mm.

Vertex half longer at middle than next the eye, almost twice as wide as long, without transverse depression. Pronotum scarcely twice as long as vertex, over twice as wide as long. Elytra with acutely pointed apices and with one to eight cross-veins between first and second anal veins. Genitalia of female characteristic of the genus. Male plates a little over half the length of pygofer, nearly parallel-margined, apices rounded and slightly diverging.

Color: Varying from pale green above and below to bright green except for elytra. Eyes reddish. Elytra, especially in male, with brown-bordered veins and with small dark spots apically. Wings smoky apically and with dark veins. Underside pale to bright green.

Holotype, female, St. Catalina Mts., Arizona, 2700 ft. *Allotype*, male, Tucson, Arizona. Both types taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus pulchellus sp. n.

A robust gray species with veins almost uniformly bordered with black. Length 5.5 mm.

Vertex half longer at middle than next the eye, twice as wide as long, rather broadly rounded with front, with a slight transverse depression. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra short and broad, apices moderately acute, claval area with more cross-veins than in any other species of the genus. Last ventral segment of female of normal shape, the posterior margin slightly sinuated. Plates of male nearly two-thirds the length of pygofer, distinctly tapering from broad bases to rather definitely acute and divergent apices.

Color: Olive-gray. Vertex with two black spots at base running parallel to inner margin of eyes. Pronotum with several black spots on anterior third parallel to anterior margin, and with large dark band of scutellum showing through posterior third. Scutellum with basal angles dark. Elytra with all veins strongly bordered with black, the cells along the elytral suture appearing lighter than the others. Eyes dark brown. Frontal arcs black. Base and spot on disc of clypeus black. Dorsum of abdomen and veins of wing black. Underside mostly greenish-gray.

Holotype, female; *allotype*, male. Both from Tempe, Arizona. Taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus pruinosus sp. n.

A pale brownish-yellow species close to *inornatus* but more robust, Length 6–6.25 mm.

Vertex half longer at middle than next the eye, slightly over twice as wide as long, without distinct transverse depression, anterior margin distinctly but not sharply angulate. Pronotum scarcely twice as long as vertex, over twice as wide as long. Elytra with strongly acute apices and with several cross-veins between first and second anal veins. Female genitalia characteristic of the genus.

Color: Pale brownish-yellow except for reddish eyes and few darker emarginations of veins, especially in apical half. Entire upper surface more or less distinctly pruinose. Underside yellowish, sometimes tinged with red.

Holotype and two *paratypes*, females, from the Santa Rita Mts., Arizona, 5000–8000 ft. Taken by F. H. Snow. Holotype and one paratype in Snow Entomological Collection; other paratype in collection of Dr. E. D. Ball.

Acinopterus inflatus sp. n.

A yellowish-white species with strongly convex front. Length 4.8–5.4 mm.

Vertex nearly twice as long at middle as next the eye, nearly twice as wide as long, rounding broadly with inflated front. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra with moderately acute apices and with several cross-veins between first and second anal veins. Female genitalia characteristic of genus. Male plates over half the length of pygofer, nearly parallel-margined, apices moderately rounded.

Color: Pale yellowish-white with veins in apical half of elytra bordered with black and with second anal veins tipped with black. Male sometimes darker with greenish cast and elytra fairly well spotted with brown. Eyes reddish. Underside yellowish or pale green. Veins of wings black.

Holotype, female; *allotype*, male; *paratypes*, two females and one male. All taken at Tucson, Arizona, by Mr. A. A. Nichol. Two paratypes in collection of Mr. Nichol; other types in Snow Entomological Collection.

Acinopterus doeringi sp. n.

A pale brown species, close to *inflatus*. Length 5.1 mm.

Vertex less than twice as long at middle as next the eye, about twice as wide as long, without transverse depression, broadly rounding with strongly convex front. Pronotum less than twice as long as vertex over twice as wide as long. Elytra with apices fairly acute and with several rather indistinct cross-veins between first and second anal veins. Genitalia of female characteristic of the genus.

Color: Pale brown and more or less pruinose above. Orange band between ocelli. Eyes dark brown. Costal plaques white and apical cells of elytra darkened. Underside slightly darker and with faint reddish tinge.

Holotype, female, Tucson, Arizona. Taken by Mr. A. A. Nichol. Deposited in Snow Entomological Collection.

Acinopterus productus var. **albidus** var. n.

Form and size of *productus*.

Color: Greenish-white above and below with just a suggestion of the green. Eyes reddish. Elytra pale except for the dark spots in the apical cells.

Holotype, male; *allotype*, female; *paratype*, male. All from Tucson, Arizona. Paratype taken by Mr. R. B. Streets; other types by Mr. A. A. Nichol. Paratype in Mr. Nichol's collection; other types in Snow Entomological Collection.

Acinopterus productus var. **fulvus** var. n.

Form and size of *productus*.

Color: Practically uniformly fulvous above and below except for reddish eyes and darker margins of tips of claval veins and some of the veins in apical portion of elytra.

Holotype, male, taken by Mr. R. B. Streets, and *allotype*, female, taken by Mr. A. A. Nichol, both from Tucson, Arizona. Types deposited in Snow Entomological Collection.

Acinopterus balli sp. n.

Varying from pale yellow to pale brown. Close to *inornatus* but with male plates wider and more pointed apically, with more cross veins between first and second anal veins and with elytra much more definitely marked with dark brown. Length 5.75–6.1 mm.

Vertex varying from half longer to nearly twice as long at middle as next the eye, about twice as wide as long, anterior margin usually distinctly angulate, with faint transverse depression. Pronotum nearly twice as long as vertex, over twice as wide as long. Elytra long and acutely pointed, with four or more cross-veins between first and second anal veins. Genitalia of female characteristic of the genus. Plates of male fairly broad, nearly parallel-margined, apices well rounded and not divergent.

Color: Pale yellow to brown. Elytra more or less marked with brown, especially apically, veins appearing distinct and lighter because frequently bordered with brown. Underside sometimes tinged with red.

Holotype, male, taken by Mr. R. B. Streets, and *allotype*, female, taken by Mr. A. A. Nichol, both from Tucson, Arizona. Types deposited in Snow Entomological Collection.

Acinopterus catalinanus sp. n.

A rather slender, brown species, close to *aridellus*, but larger. Length 5.1–5.3 mm.

Vertex half longer at middle than next the eye, scarcely twice as wide as long, with faint transverse depression, anterior margin distinctly angulate. Pronotum nearly twice as long as vertex, two and one-half times as wide as long. Elytra with fairly acute apices and four or more cross-veins between first and second anal veins. Male plates about two-thirds length of pygofer, nearly parallel-margined, apices well rounded and but slightly divergent.

Color: Almost uniform light brown except for darker borderings of elytral veins, especially near the apex. In one specimen some of the veins lightly streaked with red. Wings smoky apically and with dark veins.

Holotype and *paratype*, both males (latter with abdomen lacking), taken by Mr. E. L. Dickerson in the Sabino Canyon, St. Catalina Mts., Arizona. Types deposited in the Snow Entomological Collection.

Acinopterus parvulus sp. n.

The smallest member of the genus, elongate, greenish-brown. Length 4.7 mm.

Vertex nearly twice as long at middle as next the eye, nearly twice as wide as long, with faint transverse depression, anterior margin sharply angulate. Pronotum half longer than vertex, over twice as wide as long. Elytra unusually long and slender, apices sharply acute, with several claval cross-veins. Male plates a little over half the length of pygofer, broader at base, tapering to slightly divergent and narrower apices.

Color: Greenish-brown, the pale veins of elytra nearly all bordered with darker brown. Thorax and dorsum of abdomen black. Wings smoky apically and with black veins. Underside mostly dusky green.

Holotype, male, taken at Ontario, Calif., By Dr. E. D. Ball. Deposited in Dr. Ball's collection.

Acinopterus latus sp. n.

A very robust yellowish-brown species, close to *pallidus* but with much shorter elytra and with vertex and last ventral segment of female more produced medially. Length 5.25 mm.

Vertex half longer at middle than next the eye, over twice as wide as long, with distinct transverse depression, anterior margin not distinctly angulate and broadly rounding with front. Pronotum nearly twice as long as vertex and nearly two and one-half times as wide as long. Elytra short and very broadly rounded apically, with four or five cross-veins between first and second anal veins. Last ventral segment

of female produced a little more strongly medially than in most members of the genus; pygofer normal.

Color: Uniform yellowish-brown except for small darker brown spots scattered over elytra.

Holotype, female, labelled "Dacota, Rothemer." Deposited in the United States National Museum.

Acinopterus elongatus sp. n.

A long yellowish-brown species, close to ***variegatus*** but much more slender. Length 5.25 mm.

Vertex half longer at middle than next the eye, twice as wide as long, broadly rounding with front, transverse depression very faint. Pronotum about twice as long as vertex, over twice as wide as long. Elytra long, apices rounded though not as much as in ***latus***, without cross-veins in claval area. Plates of male moderately broad at base, tapering to fairly rounded apices, a little over half the length of the pygofer.

Color: Almost uniform yellowish-brown. Elytra with dark brown spots particularly at tips of second and third anal veins and along veins in apical half, some of the veins streaked with red.

Holotype, male, taken by Coquillet at Los Angeles, Calif. Deposited in the United States National Museum.

Acinopterus rileyi sp. n.

A small brown species, as short as ***parvulus*** but more robust. Length 4.7 mm.

Vertex half longer at middle than next the eye, half wider than long, broadly rounding with front, without transverse depression. Pronotum half longer than vertex, over twice as wide as long. Elytra short, apices distinctly rounded, with one or two very faint cross-veins on clavus. Plates of male long, broad at base and strongly narrowed to the rather acute and distinctly divergent apices.

Color: Pale brown except for darker borders of elytral veins, these more heavily bordered apically. Wings smoky apically, the veins black. Legs and pygofer tinged with pinkish.

Holotype, male, taken by C. V. Riley in Texas. Deposited in the United States National Museum.

Acinopterus bakeri sp. n.

A slender greenish-gray species, close to ***variegatus*** but more slender and vertex narrower and more elongate. Length 4.7 mm.

Vertex twice as long at middle as next the eye, twice as wide as long, anterior margin angulate, transverse depression faint. Pronotum less than twice the length of vertex, over twice as wide as long. Elytra moderately long, apices rounded just enough to place the species in the

group lacking the acute apices, claval area with several cross-veins. Plates of male quite long, two-thirds the length of pygofer, tapering from broad base for half their length, then running parallel to the well rounded apices.

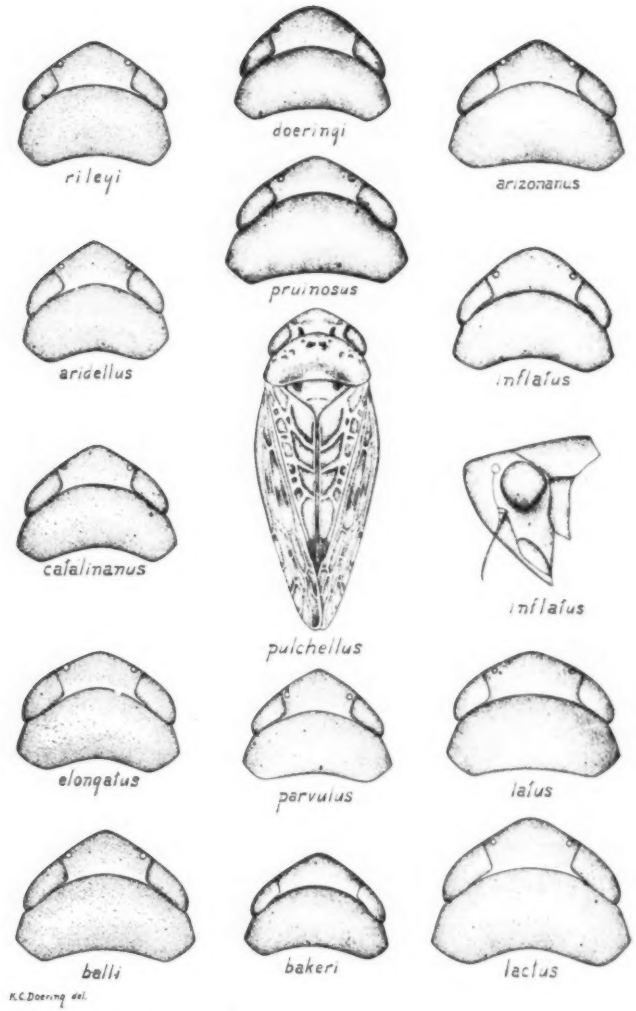
Color: Gray. Head and vertex with greenish tinge and most of the elytral veins, especially on the corium, bordered with dark brown. Eyes brownish. Underside greenish-gray.

Holotype, male, taken by C. F. Baker in Arizona. Deposited in the United States National Museum.

The external genitalia in this genus are sometimes clearly specific as in *brunneus* and *angulatus*. More often, however, the differences in the genitalia, both of male and female, are very minute, and can be seen only when the specimens of the several species are compared side by side. In most cases, therefore, the genitalia in the above new species have not been exactly described but have been spoken of as characteristic of the genus. Greater differences are manifest in the male plates than in the last ventral segment of the female though even here they are very difficult to describe because of their slightness. There seems to be no question, however, that at least very slight specific differences practically always exist.

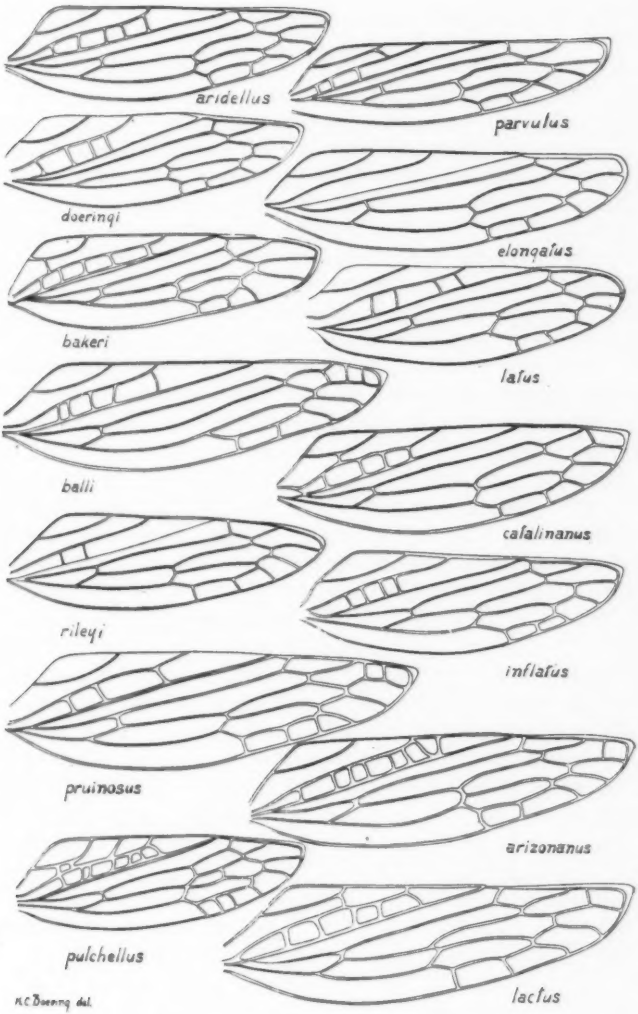
In his paper on this genus (Kansas Univ. Sci. Bul., XIV, p. 122, 1922), the writer expressed his doubt about the reference of a number of specimens to *A. inornatus* (Baker). Further comparisons between the type and most of these specimens reveal distinct differences, so that the type specimen seems to stand alone. It is particularly different from all the specimens formerly referred to this species in its paler color and the comparative indistinctness of the cross-veins of the claval area.

A. angulatus Lawson seems to be a tropical or subtropical species that has extended its range into the southern states. Through the courtesy of Mr. Harold Morrison the writer has identified specimens of this species from Mexico, Jamaica, Republic of Domingo and Cuba. Also through the courtesy of Dr. Hugo Kahl he has been able to identify specimens of this species from Brazil and Colombia. These specimens were formerly referred to *A. acuminatus*, but the latter clearly seems to be a North American species and all tropical and subtropical references to this species should be changed to *angulatus*.



Head and prothorax of species of *Acinopterus*.

Paul B. Lawson



Venation of species of *Acinopterus*.

ON THE SEASONAL MIGRATIONS OF DIONE VANILLÆ IN KANSAS.

VANCE RANDOLPH.

Dione vanillæ is a common butterfly in South and Central America, in Mexico, and in the southern part of the United States, from southern Virginia southward to Arizona and California.[1] Scudder[2] reported it as rare north of the 35th parallel, but I have collected hundreds of specimens in Kansas, and in the Ozark Mountains of Missouri and Arkansas. A few strays have been taken in West Virginia,[3] New Jersey and Pennsylvania,[4] but *Vanillæ* is really a tropical butterfly. In the central states the northern limit of its usual range falls somewhere in central or northern Kansas; it is fairly common in the southern portion of the state, but is rarely taken more than 150 miles north of the Oklahoma border.

In the tropics, of course, *Vanillæ* breeds continuously, and this is also the case in California[5] and in Florida, although in the latter state the butterflies are much less abundant during the winter months. In the northern part of its range, however, *Vanillæ* appears only for two or three months in the year, and nobody knows where or in what stage of development it passes the winter.[6] My own observations of this butterfly were made near Pittsburg, in southeastern Kansas, in the period between 1915 and 1925. For ten summers I collected Lepidoptera in this region, and reared hundreds of specimens of *Vanillæ* under all sorts of conditions,[7] but was never able to determine how these butterflies managed to survive the Kansas winter.

---

[1]Holland, W. J. *The Butterfly Book*, New York, 1898, p. 97.

[2]Scudder, Samuel Hubbard. *The Butterflies of the Eastern United States and Canada*, Cambridge, Mass., 1889, Vol. III, pp. 1811–1819.

[3]Edwards, W. H. Description of the Preparatory Stages of Agraulis vanillæ, Linnaeus, *Canadian Entomologist*, Vol. XII, 1880, p. 125.

[4]Maynard, C. J. *Manual of North American Butterflies*, New York, 1891, p. 50.

[5]Wright, William Greenwood. *West Coast Butterflies*, San Bernardino, 1905.

[6]Scudder, Samuel Hubbard. *The Butterflies of the Eastern United States and Canada*, Cambridge, Mass., 1889, Vol. III, pp. 1811–1819.

[7]Randolph, Vance. Life History and Habits of Dione vanillæ, *Transactions Kansas Academy of Science*, Vol. XXX, 1919–1921, pp. 351–362.

The butterfly itself never appears in Kansas until about August 1st, and I have never taken one later than the 28th of November. This late appearance, and the fact that the first specimens to appear are apparently fresh and in good condition, does not lend any particular support to the view that *Vanillæ* hibernates as an imago. A ten-year search has failed to locate a single living chrysalid later than November 21st, and since the butterfly usually emerges only seven or eight days after pupation, we may be fairly certain that *Vanillæ* does not sleep through the cold weather in the pupa state. As to the caterpillars, those which I have reared always either pupated or died before November 15th, and a most painstaking examination of the leaves and dirt near the food-plant has not uncovered a single caterpillar in the winter time. There is no evidence whatever that *Vanillæ* passes the winter as a caterpillar. The eggs are deposited on the green leaves of the food-plant, and the incubation period is only 6 or 7 days. I have never found eggs earlier than July 27th or later than September 28th, and there is no reason to suppose that they ever live through the first frost.

Thinking to settle this question once for all, in the summer of 1921 I transplanted a *Passiflora* vine into a large pot, and enclosed the whole thing in a fine-meshed wire cage. Into this cage I put about 500 living specimens of *Vanillæ*—eggs, caterpillars, chrysalids and butterflies. The first cool weather apparently killed the last of these, but on December 25th I opened the cage and examined its contents very carefully, sifting every bit of the dirt through a fine wire screen, and examining it with a powerful reading lens. Not a single living specimen did I find—no egg, no caterpillar, no chrysalid, no hibernating imago. The following year I repeated the experiment, except that this time I did not open the cage at Christmas, but allowed it to remain locked until August 30, 1923. No sign of life appeared—not one *Vanillæ* had survived the Kansas winter.

If *Vanillæ* does not winter in Kansas, we may assume that each year a few of the butterflies drift up from the South, breed as long as the Summer lasts, and are destroyed with all their progeny by the first frosty weather. I am told that *Vanillæ* appears in southern Arkansas and Oklahoma about the middle of June, but have never seen a specimen myself

earlier than July 20th. It certainly flies earlier than this in Texas, since Edwards[8] reports eggs deposited in Dallas on June 19th. It has been suggested that these butterflies hibernate in some of the Southern States; it may be, however, that they do not hibernate anywhere, but follow the warm weather north from Mexico, where they are said to breed the year round. It is not necessary to suppose that an individual butterfly flies from Mexico to southern Kansas, but it may be that a few individuals drift north for several hundred miles, and deposit the last of their eggs at the end of the journey. Some 25 days[9] later, when the butterflies of this brood emerge, the season is still farther advanced, and if a few of these also wander northward it might be possible for the third or fourth generation to arrive in Kansas by the early part of August. It would certainly be interesting to know the precise dates on which *Vanillæ* first appears at a series of points between southern Kansas and the northernmost region in which it breeds continuously. This information, unfortunately, is not available at present.

The only positive conclusion which may be drawn from my observations and experiments is this: *Dione vanillæ* does not spend the winter in Kansas. My remarks about migration are highly speculative, of course. It is very difficult to find out anything definite about the migration of butterflies, and for this reason, it seems to me, every scrap of information on the subject should be carefully preserved for the use of future investigators.

---

[8]Edwards, W. H. Description of Preparatory Stages of Agraulis vanillæ, Linnaeus, *Canadian Entomologist*, Vol. XII, 1880, p. 125.

[9]Edwards, W. H. Description of Preparatory Stages of Agraulis vanillæ, Linnaeus. *Canadian Entomologist*, Vol. XII, 1880, p. 125.

THE HIPPOBOSCID FLY, ORNITHOMYIA AVICULARIA LINNAEUS, AS A CARRIER OF MALLOPHAGA.

H. E. Ewing,
U. S. Bureau of Entomology.

It is of fundamental importance in the study of questions relating to the distribution and phylogeny of parasites to know of those agencies or conditions which break down natural barriers to their spread from host individual to host individual and from host species to host species. In the case of host species of solitary habits their ectoparasites are thought to be marooned on such species much in the manner of inhabitants of an island. In general it may be stated, as held by Kellogg (1915), that the lice of such species have, through association, followed the same road in their phylogenetic development as their hosts; or, in other words, that hosts and parasites have had a parallel phylogeny.

In those striking examples, however, where we find closely related ectoparasitic species infesting diverse host groups the question arises, by what agencies did their ancestors get from the host species of one group to those of another?

As far back as 1895 Sharp suggested that "possibly Mallophaga may be transferred from one bird to another by means of the parasitic two-winged flies that infest birds." He had previously recorded (Sharp, 1890) a case in which a bird-fly had been captured with several Mallophaga adhering to it.

Some years later Jacobson (Jacobson, 1911) reported the collecting of a Hippoboscid (*Ornithoeca pusilla*) which had a Mallophagan "clasped between the legs." This bird-fly had escaped from a bird, *Eucichla cyanura*, immediately after Jacobson had shot it.

After reflecting on the possible significance of this observation Jacobson states (1911, p. 169) that, "it may be presumed that the habit of the Mallophaga to use Hippoboscidæ as conveyance, will be found to be quite a common occurrence with these insects, and more attention should be paid in the future to this point." Indeed Jacobson's presumption has been fully justified, for up to the present no less than eleven authentic

cases have been recorded of Hippoboscids carrying Mallophaga or at least of their being found with Mallophaga attached to them.

A short summary of most of these cases was given by McAtee (1922). After summarizing eight cases McAtee remarks

FIG. 1. *Ornithomyia avicularia*, greatly enlarged, showing a biting louse, *Degeeriella interposita* (Kellogg), attached to the right posterior aspect of the abdomen. (Photo by Pratt).

that it is rather surprising that so many of the records should be for the Hippoboscid genus *Ornithomyia*. The present writer would also like to add, after reporting two new cases for this genus, that it is even more surprising that so many of the records are for a single species of *Ornithomyia, O. avicularia* Linn.

New Records.

Dr. J. M. Aldrich recently (1926) called my attention to two specimens of *Orithomyia avicularia* that were found to harbor biting lice. One of them which had been collected by R. Boulton from a song sparrow, *Melospiza melodia melodia*, at Gates Mills, Ohio, June 30, 1926, had two specimens of *Degeeriella interposita* (Kellogg), an adult male and female, attached to the postero-lateral aspect of the abdomen. These lice were so attached that their bodies produced a perfect symmetry with that of the host, each having the head forward and the body extending backward along the side of that of the fly. The body wall around one of these lice was dissected away, the remaining piece being held in the mandibles of the louse. When this louse was mounted on a microscope slide it was found that the Mallophagan had bitten into the body wall with the mandibles. In doing so it had clasped loosely a small seta, but this fact appears to have been incidental. It was especially interestint to ascertain the exact method of attachment, as this point had been overlooked in most of the cases previously reported.

The other fly (see Figure) had been taken by R. Boulton from a catbird, *Dumetella carolinensis*, at Gates Mills, Ohio, July 29, 1926, and had one specimen of *Degeeriella interposita* (Kellogg) attached in exactly the same way that the other two were attached.

A tabular summary of the nine cases involving the bird-fly *Ornithomyia avicularia* is given on next page.

Ornithomyia avicularia Linnaeus Chiefly Concerned.

After reviewing the known records of Hippoboscids carrying Mallophaga it is found that in eight of the eleven cases *Ornithomyia avicularia* is mentioned as the transporting species and in the remaining cases one named host, *Ornithomyia anchineura* Speiser, should, according to Ferris and Cole (1922), be considered as a synonym of *O. avicularia*. Of the two other cases, in one instance the fly was determined as an *Ornithomyia* but the species was not given. It develops then that in only a single instance, that reported by Jacobson (1911) was the bird fly known definitely not to be *O. avicularia*. When one reflects that there are at least seventeeen genera of bird-infesting

Hippoboscidæ and about three times as many species he is convinced that unusual conditions prevail for the attachment of biting lice to this one fly species.

TABULATION OF RECORDS OF MALLOPHAGAN INFESTATION OF ORNITHOMYIA AVICULARIA LINNEUS

Date	By Whom Reported	Bird Host	Country	Mallophagan Species	Number of Attached Lice	Remarks
1890	D. Sharp	Not reported	England	Not determined	"Several specimens"	"Firmly adhering apparently by the mandibles."
1903	R. Forsius	*Tetrao tetrix*	Finland	*Degeeriella quadratula* (N.)	1	Fastened at base of wing.
1908	R. Forsius	*Corvus cornix*	Finland	*Degeeriella uncinosa* (N.)	2	One on hind tibia and one on abdomen.
1910	B. Wanach	Probably *Planesticus merula merula*	Germany	*Philopterus* sp.	1	On abdomen.
1919	C. W. Johnson	*Perisoreus barbouri*	Quebec, Canada	Not determined	2	Attached one on each side of abdomen.
1920	W. L. McAtee	Not known	Saskatchewan, Canada	*Degeeriella rotundata* (O.)	1	Attached by mandibles to upper surface of abdomen.
1920	W. L. McAtee	*Corvus brachyrhyncos hesperis*	Oregon, United States	*Degeeriella rotundata* (O.)	1	Attached by mandibles to upper surface of abdomen.
1926	This paper	*Melospiza melodia melodia*	Ohio, United States	*Degeeriella interposita* (K.)	2	Attached to body-wall of abdomen by mandibles.
1926	This paper	*Dumetella carolinensis*	Ohio, United States	*Degeeriella interposita* (K.)	1	Attached to body-wall of abdomen by mandibles.

One Mallophagan Genus Chiefly Involved.

While one Hippoboscid fly is almost the sole carrier of the Mallophaga, several species of lice are involved, yet it is remarkable that out of the seven cases where the lice were determined to genus or species, six of them should prove to belong to the single genus *Degeeriella*. And in the other case, the species belongs to the genus *Philopterus*, a genus never separated from *Degeeriella* by any clear cut generic character.

The Bird Host Species.

The bird hosts for all cases where *Ornithomyi aavicularia* is concerned are as follows, in so far as known:

European blackbird, ***Planesticus merula merula.***
European black grouse, ***Tetrao tetrix.***
European hooded-crow, ***Corvus cornix.***
Canadian jay, ***Perisoreus barbouri.***
Western crow, ***Corvus brachyrhynchos hesperis.***
Song sparrow, ***Melospiza melodia melodia.***
Catbird, ***Dumetella carolinensis.***

Habits of Hippoboscid Favorable for a Wide Distribution of the Lice Carried.

It is important to note that in no two cases reported of *Ornithomyia avicularia* carrying lice has the bird host been of the same species. Not only this, but such unrelated birds as the European blackbird, a thrush, the European black grouse, the American song sparrow and the hooded crow are included. The habits of this fly in visiting bird species of such a wide range, coupled with its demonstrated habit of frequently carrying different louse species, indicates that it is an agent of great importance in the transfer of lice from bird species to bird species as it changes hosts.

Why do the Lice Concentrate Chiefly on a Single Bird-Fly Species for Attachment?

It is certainly surprising to find that nearly all the records of attachment have to do with a single Hippoboscid species, *Ornithomyia avicularia*, when we further reflect that there are no records for such a common bird-fly as *Lynchia americana* (Leach), a species more commonly collected than *O. avicularia.*

The conclusion is almost forced upon us that there must be something in the habits or nature of *O. avicularia* that causes the lice to attach to it. Just what this is is only a matter of conjecture. The following suggestions in the form of questions are given:

1. Could the lice be attached to the bird-flies for reasons other than transportation?

2. Are the lice attempting to obtain some of the blood the flies have imbibed from their bird hosts? It has been shown that some bird lice will occasionally eat blood (dried or liquid?).

3. Do the lice attach to the flies because the latter have temporarily become warmed by contact with the skin of the bird host?

4. Could the bird-fly give off any odor or secretion that is attractive to the lice?

Before closing it should be noted that in one instance the lice were found on flies that had flown from the freshly killed bird; hence they had attached themselves to the dipteron before the body of the bird host had become cool. Mallophaga usually leave the body of the dead host only after it has become cold, and at such times will spread to surrounding objects of almost any kind.

Direct observations on parasitized birds under controlled conditions would appear to be the next step toward the solution of these and other questions in regard to the relationships of *Ornithomyia avicularia* to its bird hosts and to its transported lice.

LITERATURE CITED.

For bibliography relating to cases of Mallophaga attaching themselves to Hippoboscids, see article by McAtee (1922).

Ferris, G. F., and **Cole, F. R.** 1922. Parasitology, Vol. XIV, p. 199.

Jacobson, E. 1911. Mallophaga Transported by Hippoboscidae. Tydschr. v. Ent., Vol. LIV, pp. 168–169.

Johnson, C. W. 1922. Psyche, Vol. XXIX, pp. 81–82. (Reference not given in McAtee's list).

Kellogg, V. L. 1915. A Fourth Mallophagan Species from the Hoatzin. Science, Vol. XLI, pp. 365–367.

McAtee, W. L. 1922. Bird Lice (Mallophaga) Attaching themselves to Bird-flies. Ent. News, Vol. XXXIII, p. 90.

Sharp, D. 1890. Proc. Ent. Soc., Lond., p. XXX.
1895. Cambridge Natural History, Vol. v, pt. I, p. 350.

NOTES ON THE BIOLOGY AND HABITS OF THE PERUVIAN COTTON SQUARE WEEVIL (ANTHONOMUS VESTITUS BOHM).

W. E. HINDS
Entomologist, Louisiana Experiment Station.

During a brief visit to the central coastal cotton growing valleys of Peru in February and March, 1926, the writer had opportunity to make some further observations on the biology and habits of the Peruvian cotton square weevil, which is a rather important cotton pest in that country and might possibly some time be introduced into the cotton belt of the United States.

Those who are familiar with the biology of the Mexican cotton boll weevil (*Anthonomus grandis*—Bohm) will be struck with the many points of close resemblance in the development and activity of these two species.

The first known specimens of the Peruvian species were collected from the Island of Puna off the coast of Ecuador, presumably, between 1851 and 1853. The species was described by Boheman in 1859, but with no information as to its possible host relationships or possible economic importance. Apparently the next record regarding the species came through the work of Dr. C. H. T. Townsend in 1910 while he was working in the northern portion of Peru. Dr. Townsend was actively connected with early investigations on the Mexican cotton boll weevil and was, therefore, unusually well prepared to appreciate the importance of this Peruvian weevil. At that time, he sent to the United States National Museum some 68 specimens, mostly bred from cotton squares taken in the Chira River Valley in the extreme northern part of Peru and only about 2° latitude south of the location of the original specimen. From these specimens Dr. W. D. Pierce redescribed the species in the proceedings of the United States National Museum Volume 42, pages 156 to 157. Dr. Townsend published an article on this species in 1911 in the Journal of Economic Entomology, Volume 4, No. 2, pages 241-248.

The observations given herewith were made in the valley of the Canete River located at 13° south latitude, or nearly 600 miles further south than the locality in which Dr. Townsend had worked. Upon examining specimens taken in this more southern territory, Dr. Townsend declared that they were identical with those taken by him fifteen years earlier in Northern Peru. He expressed the view that the species would be found in all Peruvian cotton growing valleys, and stated that he had not found it in Brazilian cotton growing areas.

In the Canete Valley the species was found to be of common occurrence in practically all fields, being active from January—at the beginning of their squaring season—to the end of the growing season and frequently causing rather serious damage. The Peruvian square weevil appears to attack by preference squares that are less than one-half inch in diameter and by far the greater portion of their work appears to be in squares only about one-quarter inch in diameter. Very little feeding or oviposition occurs in even the smallest bolls. The reason for this selection of small squares appears to be found in the fact that the snout of this small species, which is from 1.2 to 1.7 mm. long, is too short to penetrate through the floral envelope and enable them to feed upon the pollen sacs in squares that are more than seven-sixteenths inch in diameter. The species shows the same dependence upon pollen as food necessary for normal egg production as does the Mexican cotton boll weevil. The feeding period between the emergence and the deposition of their first eggs appears to depend largely upon their ability to secure this immature pollen source of food. Food material passes through the elementary canal in from 12 to 13 hours; and the period of preoviposition feeding varied from slightly more than 24 hours where the female had access to a cut-open square to 6 days where they had difficulty in securing pollen.

The adults of this species are difficult to locate in the field. They are very small, ranging from about 2.5 to 4 mm. in length and are of a light tan color, which renders them very inconspicuous. Furthermore they are extremely shy, run rapidly and drop or take flight far more readily than does the Mexican cotton boll weevil. During the examination of many thousands of squares and the collection of large numbers of weevil-infested squares from the stalks, only three adults were absolutely observed in the field. There was no difficulty, however, in

locating the squares attacked by these weevils. The infested squares flare widely and fall to the ground more quickly after oviposition occurs than do those attacked by the boll weevil. The feeding habits are in general very similar to those of the boll weevil, except that the majority of feeding punctures are made by both males and females through the thinner, more tender areas just above the edge of the sepals rather than through the thicker basal portion of the square. Among the 50 weevils of both sexes handled in the Laboratory, an average of 3 feeding punctures per day was made.

Egg deposition normally occurs in a somewhat different location from that chosen by the boll weevil. The eggs are placed almost invariably in the upper part of the constricted basal portion of the square, the egg resting in the base of the petal rather than in the surface of the pollen sac, as is the case with the boll weevil. The frequent occurrence of two larvæ, pupæ or adults per square indicates clearly that on account of its smaller size this species is not nearly as particular in restricting its egg deposition as is the boll weevil. The egg punctures do not always show clearly the mucus and pollen particles closing the opening to the puncture, and in the laboratory it was noticed that eggs were deposited frequently within a feeding puncture. In the field proliferation occurs more quickly with the egg in the base of a petal than it does with the boll weevil, where the egg is placed in a pollen sac. The "wart" is not clearly defined, but the swelling due to the proliferation causes a distinct asymetrical bulge, on that side of the base of the square and just above the point of puncture, which is very characteristic of the work of this species. On hatching the young larva feeds for the first day or two in this proliferous mass before it works its way up through it and into the pollen sacs where its later feeding occurs. The infested squares appear to fall to the ground as a rule in 5 or 6 days instead of the 10 days usually required with the boll weevil. Therefore, most of the development of the larva occurs after the square has fallen to the ground. As many as 25 infested squares were picked from a single plant and were evidently the work of one female. In the laboratory only from 3 to 5 eggs per day were obtained per female.

Our records upon the time required for development for each stage were not sufficiently numerous to be considered fully

accurate; but the following periods were shown in the cases observed at an average temperature of 79° Farenheit:

Egg period, 66 to 72 hours.
Larval period, 8 to 9 days.
Pupal period, 3 to 6 days.
Unemerged adult period, 2 to 3 days.
Total development from oviposition to emergence of adults, 15 to 20 days, or practically the same period as that for the Mexican cotton boll weevil.

It was impossible to determine the average length of adult active life. Many weevils of both sexes died under laboratory conditions during the first week; and the work was closed at the end of the second week while many more of the weevils were still active.

The sexes are distinguished upon practically the same characters as those used with the Mexican cotton boll weevil. The male's snout is distinctly shorter, thicker and rougher than is that of the female. The males average slightly smaller than females in size, but the variation of size in each sex is considerable. The pygidial plate in the male is more distinctly visible than in the female; and the tip of the body appears to taper somewhat more abruptly. Mating is frequent and indiscriminate, usually lasting from 4 to 7 minutes.

From our limited observations we are inclined to believe that the reproductive capacity of this species is considerably less than that of the boll weevil; and its capacity for damage to the cotton crop is, we believe, less than half that of the boll weevil. It is evidently capable of surviving under decidedly arid conditions, as the territory in which these observations were made receives no rainfall and irrigation is practiced only at intervals of several weeks during the fruiting season, and may not occur at all during this period. The species certainly deserves more extended and detailed investigation.

NOTES ON THE COMPUTING OF MEAN TEMPERATURES FOR BIOLOGICAL USE.

C. R. CUTRIGHT,
Ohio Agricultural Experiment Station, Wooster, Ohio.

Practically all biological papers give some mention of the effect of various temperatures on the plant or animal under discussion. Considering this striking expression of the importance of the temperature factor it is indeed surprising that biologists have not given more time to the study of temperature means. It is true that we have elaborate devices for the recording and control of temperatures but in correlating the actual outdoor readings with insect and animal activities we are woefully weak. We consider that one of the first steps in correcting this weakness is the study and development of a correct and convenient method for computing mean temperature over a short or long period of time, as the case may demand.

Climatologists are particularly interested in mean temperatures and have made many studies concerning them. However, their interest is usually in an accurate mean temperature for long periods of time, such as a month or a year. For many biological uses, records such as these are obviously unsuited. For instance in working with an aphid that develops from birth to reproductive capacity in seven or eight days in summer, the monthly mean temperature is of little value. This is also the case in any short time biological process. At present the mean temperatures issued by the U. S. Weather Bureau are computed by adding the maximum and minimum temperature for the day and dividing the result by two. Due to the variable changes in temperature during the day this method admittedly is inaccurate and will sometimes vary from the true daily mean, as determined by hourly readings, by as much as 10 degrees F. Also these variations may be cumulative at certain periods, thus increasing their importance. Hartzell (3) has pointed out that if the maximum and minimum readings are taken after 8 p. m. that the discrepancies are much less if a long period of time is considered. Hann (2) recommends that readings be taken at 6 a. m., 2 and 10 p. m. to secure an accurate average,

but this also applies to long periods of time. Most biologists use self-recording thermographs and compute a mean temperature by taking hourly or two hour readings from the graphs. This is a laborious and time consuming method to say the least.

Some time ago it was necessary to obtain daily and weekly mean temperatures from data on a drum type soil thermograph that had accumulated over a period of two years. To avoid this lengthy and monotonous task an attempt was made to develop a shorter method. The use of the planimeter in computing mean temperatures has been mentioned by Hartzell (3) and Sanderson (5) but as far as we are aware the technique that was developed in handling this instrument is original. Two methods of computing mean temperature with the aid of the planimeter were devised. First, a method using the total area of the temperature chart as a base of measurement against which the area, either above or below the temperature curve, is computed as a fractional part. Instead of computing this fractional area by arithmetical methods we can easily construct a graph for this purpose. On the abscissa, the units of area in the temperature chart may be plotted. (This must also take into account the time unit, which may be a week, a day or several days. A separate graph should be made for each time unit in which one wishes to compute mean temperature). On the ordinate plot the temperature range of the chart. A curve joining the point of intersection is then drawn. When the fractional area is obtained with the planimeter, locate this on the abscissa and run across the graph to the curve, then drop to the ordinate and the mean temperature is read. It is probable that a method somewhat similar to this was used by Sanderson (5) and Hartzell (3), though we have no example of their technique.

The second method is useful in case we do not wish to construct a graph and have only a few charts to work over. It is more complicated and is given in detail as follows: (Fig. 1, Plate XVI).

1. Obtain the maximum and minimum temperatures for the period of time, any period from one to seven days may be used, during which it is desired to obtain a mean and subtract the latter from the former. This gives the temperature range.

2. Obtain the area bounded by parallel, horizontal lines running through the maximum and minimum readings, and the vertical or time lines inclosing the period to be considered. This is the total area.

3. Likewise obtain the area of that section of the rectangle lying above the temperature curve. This is the fractional area.

4. Divide the fractional area by the whole area. This gives the fractional area in terms of percent.

5. Multiply the temperature range by the percent. The product is degrees of temperature corresponding to the fractional area.

6. Subtract this from the maximum temperature and we have the mean temperature for the period.

The two methods when applied to the same charts give almost identical results. During the course of a year, in which the mean temperature was calculated for each week by the two methods, the maximum difference occurring in any week was .8 degree F. The average difference for the year was less than .3 degree F. The following table gives some idea of the actual differences that occurred between weekly mean temperatures so computed. During this period the 1st method averaged .07 degree F. higher than did the 2nd.

TABLE I.

Comparison of Weekly Mean Temperatures, Computed by the Two Planimeter Methods.

First Method	Second Method	First Method	Second Method	First Method	Second Method
39.8	39.5	59.6	59.2	71.2	71.6
39.0	39.2	66.6	66.3	76.5	76.0
43.3	42.9	63.3	62.7	71.2	70.8
35.4	35.7	46.3	46.1	69.8	69.8
53.9	54.5	48.3	47.9	64.9	65.3
47.8	47.6	52.5	52.2	72.8	72.6
53.2	53.5	58.2	58.3	73.0	72.8
42.6	42.7	62.3	61.6	71.2	71.0
50.0	49.9	81.8	81.7	71.0	71.3
55.4	55.2	70.4	69.9	74.3	74.9
60.1	60.3	72.0	71.5	73.2	73.5
65.0	64.8	66.2	66.2	69.2	69.4

The same systems can, of course, be used in calculating humidity averages.

No sooner had these methods been developed than the question arose as to how closely temperatures so computed would correspond to temperatures calculated by the other methods. I, therefore, took the data from eight weekly sheets, as recorded on a soil thermograph and computed the weekly mean temperature by each of four different methods. These were: daily maximum and minimum readings, twelve daily readings, twenty-four daily (hourly) readings, and the second planimeter method as described above. The weekly maximum and minimum mean was computed by averaging the seven daily means of this type. The mean for the twelve and twenty-four daily readings was found in the same way but the planimeter mean was taken directly from the graph. Figure 2 shows the results of this study. Since the twenty-four daily readings constitute a reliable method of computing the mean, I have plotted this directly on the heavy horizontal line. The other means were then plotted according to the amount of variation from this. The wide variation, from 2 to 5 degrees, between the maximum and minimum mean and the other three means is striking, but even more noticeable is the closeness of the latter three means to each other. The mean as determined by the planimeter varies at most only .3 degree F, while the mean determined by twelve daily readings does not differ more than .1 degree.

Figure 3 shows work with thirty weekly sheets taken from an aerial thermograph. The plan of this graph is the same as Figure 2 except that the planimeter mean is plotted on the horizontal line and the mean as determined by twenty-four daily readings was not computed. There is some indication that at times the planimeter mean is more accurate than the mean of the twelve daily readings. For example, when the maximum and minimum mean shows a wide variation, as in the week of May 25th, this is partially corrected by the mean of the twelve daily readings, which error is still further reduced by the planimeter. The greatest variation in this series amounts to .7 degree F.

We then compared the planimeter method with the others in computing the mean temperature for shorter lengths of time, which of course meant that the areas to be measured by the

planimeter would be smaller. Two things led us to fear that the planimeter method would not be accurate on such areas: 1st, the planimeter vernier is not finely graduated and readings from it must at times be approximated; 2nd, in moving the pointer around the area it is not always possible to keep it exactly on the line.

Fifty days were taken at random throughout the year from soil thermograph records and the mean for each was computed by the four methods. Figure 4 is of the same construction as Figures 2 and 3, with the twenty-four daily reading mean plotted on the horizontal line. The variation of the maximum and minimum mean from that of the twenty-four daily readings ranges from 0 to 6.7 degrees with an average error of about 3 degrees. The greatest variation of the planimeter mean is 1.4 degree with an average variation of less than .3 of a degree. This shows the great improvement effected by this method. However, the greatest variation of the mean of the twelve daily readings is .6 of a degree with an average deviation of approximately .1 degree.

Figure 5 gives the same data as Figure 4 but the planimeter mean is plotted on the horizontal line. The very small amount of variation between the means of the twenty-four and the twelve daily readings is clearly shown. This in connection with Figure 4 and together with a close study of the daily curves as they appear on the weekly temperature charts show us that the planimeter mean of daily temperature is not quite as accurate as the means established by twenty-four or twelve daily readings.

The time required to compute a weekly mean temperature, using twenty-four readings for each day, is between 40 and 50 minutes for one's self, a clerk and an adding machine. By using a planimeter one can calculate an accurate weekly mean temperature in about 5 minutes, without the services of the clerk and machine. Because of this great saving in time and labor we believe that the planimeter methods can be used, especially in instances where a mean temperature is desired for periods covering several days or a week.

To summarize briefly, the mean temperature computed by the planimeter for periods as short as a day is not quite as accurate as the means of the twenty-four or twelve daily readings. It is, however, a great improvement over the usual

maximum and minimum mean. The mean of twelve daily readings is, for most purposes, practically as accurate as the mean of the 24 daily (hourly) readings.

The planimeter mean as determined for periods of time such as a week is accurate and convenient and because of this can be used to advantage.

BIBLIOGRAPHY.

(1) **Donnel, C. A.** Mo. Weather Review 40:708, 1912.
(2) **Hann, (R. DeC. Ward** Translation.) Handbook of Climatology. 1903.
(3) **Hartzell, F. Z.** Comparison of Methods for Computing Daily Mean Temperatures. Technical Bul. 68, N. Y. Agr. Exp. Sta. 1919.
(4) **MacDougal, D. T.** J. N. Y. Bot. Garden 3:127-131, 1902.
(5) **Sanderson, E. D.** Jr. Ec. Ent. 1:56-65, 1908.
(6) ———. Jr. Ec. Ent. 3:113-139. 1910.

EXPLANATION OF PLATE XVI.

Fig. 1. An example of the planimeter method.

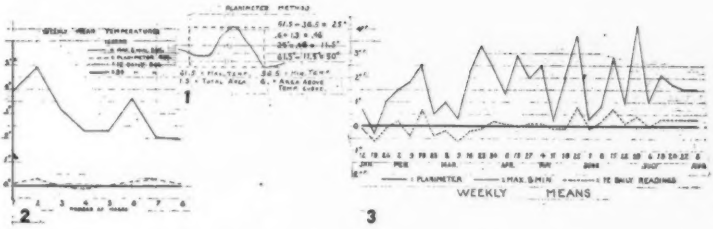
Fig. 2. Weekly mean temperatures as computed by four different methods. Twenty-four daily reading mean plotted on the base line.

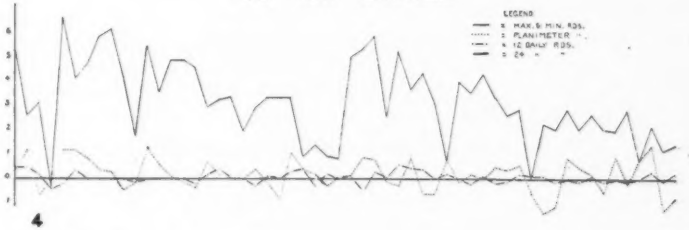
Fig. 3 Weekly mean temperatures. Planimeter mean plotted on the base line.

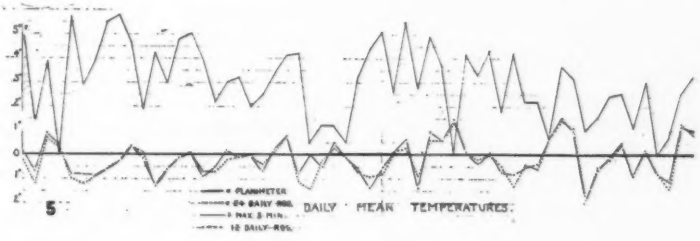
Fig. 4. Daily mean temperatures. Twenty-four daily reading means on the base line.

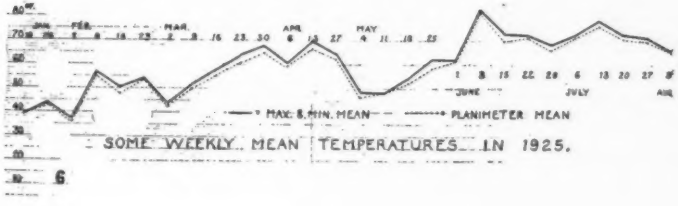
Fig. 5. Daily mean temperature. Planimeter mean on the base line. (Same data as Fig. 4)

Fig. 6. Difference between mean temperatures as determined by the maximum and minimum and the planimeter method. Actual weekly mean temperatures for a portion of 1925 at Oak Harbor, O.


1
2
3
WEEKLY MEANS


DAILY MEAN TEMPERATURES
4


5
DAILY MEAN TEMPERATURES.


MAX. & MIN. MEAN
PLANIMETER MEAN
SOME WEEKLY MEAN TEMPERATURES IN 1925.
6

C. R. Cutright

A NEW SPECIES OF HYDROMETRA FROM NORTH AMERICA.

H. B. HUNGERFORD,
Department of Entomology, University of Kansas, Lawrence.

In a collection of some aquatic Hemiptera sent to me by Mr. Clarence O. Bare I find a species of Hydrometra that is not described in Mr. J. R. de la Torre-Bueno's splendid paper entitled "The Family Hydrometridæ in the Western Hemisphere" which appeared in the *Entomologica Americana* Vol. VII (New Series) No. 2, issued December 27, 1926.

Hydrometra barei sp. new.

Size: Length of male, 7.5 to 8 mm. Length of female, 9.3 mm. The head is not provided with a ventral groove. The anteocular portion of the head is to the postocular portion of the head as forty-three is to twenty-three, the formula being therefore AO : PO :: 43 : 23. The tip of the rostrum surpasses the eyes by three-fifths of the postocular distance. The anterior femur does not attain the base of the antenna. The relation of the segments of the antennæ beginning with the basal one is represented by the following formula: 10 : 20 : 55 : 28 in the male. The female segments are slightly shorter proportionately. The male processes on the ventral side of the sixth segment are linear, oblique and located near the anterior margin. The distance between these processes is more than twice the length of either process.

The caudal spine of the male is long, straight and directed backward. The last segment of the male viewed from above is very slightly expanded in its caudal portion and longer (including the spine) than the preceding segment. The caudal spine of the female is also long, sharply acuminate and four-fifths as long as the preceding segment surpassing the tip of the body by nearly half its length. Two pits are present on the pro and meso-acetabula.

Described from two pairs taken at Plant City, Florida by Mr. C. O. Bare. Holotype and allotype in the University of Kansas Entomological Collection.

THE VARIABILITY OF APHIS GOSSYPII.

C. H. Batchelder,
University of Maine.

SUBJECT MATTER.

Purpose of the investigation.
Source of the material.
Technique employed.
The variability of external characters.
The correlation of external characters for length.
Varibility and the foodplant.

The Purpose of This Investigation.

Because of confusion in economic literature and in collections, concerning the identity of *Aphis gossypii*, it is desirable to know the range of variation in this species, especially with reference to such external structures as may be considered of value as "key characters."

Source of The Material.

The original stock collections were made by Dr. Edith M. Patch from garden cucumber, *Cucumis sativus*, on August 21, 1923. The stock was kept on squash, *Cucurbita maxima*, under laboratory and insectary conditions through several generations and from this host-plant transfers were made as follows:

Sublot 2; squash, from which material was mounted on September 30, October 4, October 25, November 20, and November 26.

Sublot 4; to Begonia on August 28, from which material was mounted on October 4, October 25, and November 20.

Sublot 5; to Shepherd's Purse on September 20, from which material was mounted on October 4.

Sublot 6; to squash in air temperature insectary on August 21, from which material was mounted on October 23.

Sublot 7; to Oenothera biennis on September 20, from which material was mounted on November 20, December 1, and December 24.

It will be noted that this method of collecting the material made available for examination only plant-lice that had been

bred under controlled conditions. This precluded the introduction of species other than *A. gossypii*. Conditions were otherwise controlled consistently enough to expect comparative uniformity in the specimens.

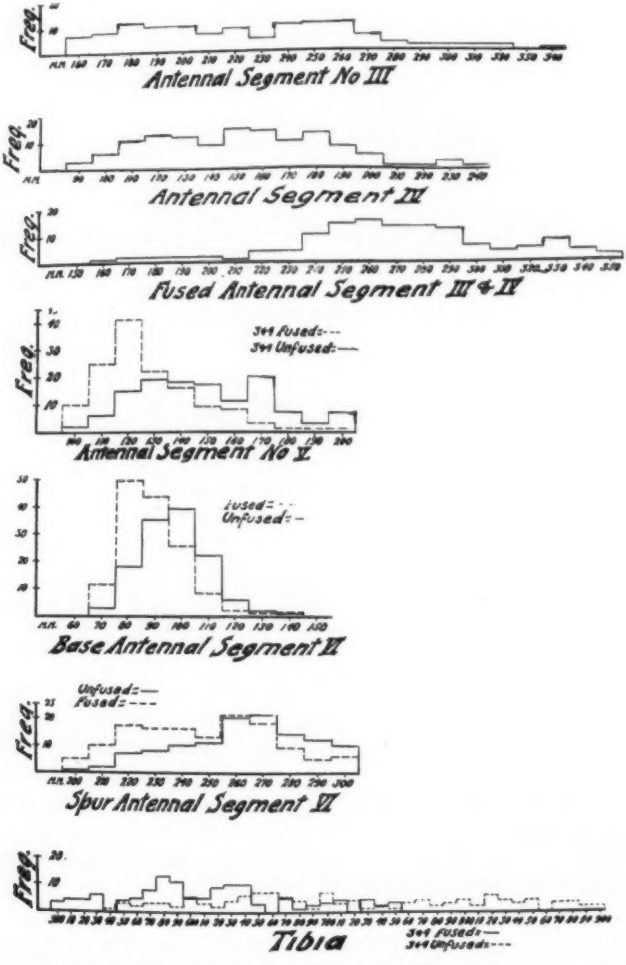


Fig. 1. Histograms illustrating the variability in length of antennal segments and the metathoracic tibia in the wingless form of *Aphis gossypii*. Antennæ in which segments 3 and 4 are fused are compared in length with those in which these segments are not fused.

The Technique Employed.

Balsam mounts had been very carefully made on the collection dates mentioned above. In addition, preparations of *A. gossypii* were available from *Cucumis melo*, *Cucurbita pepo*,

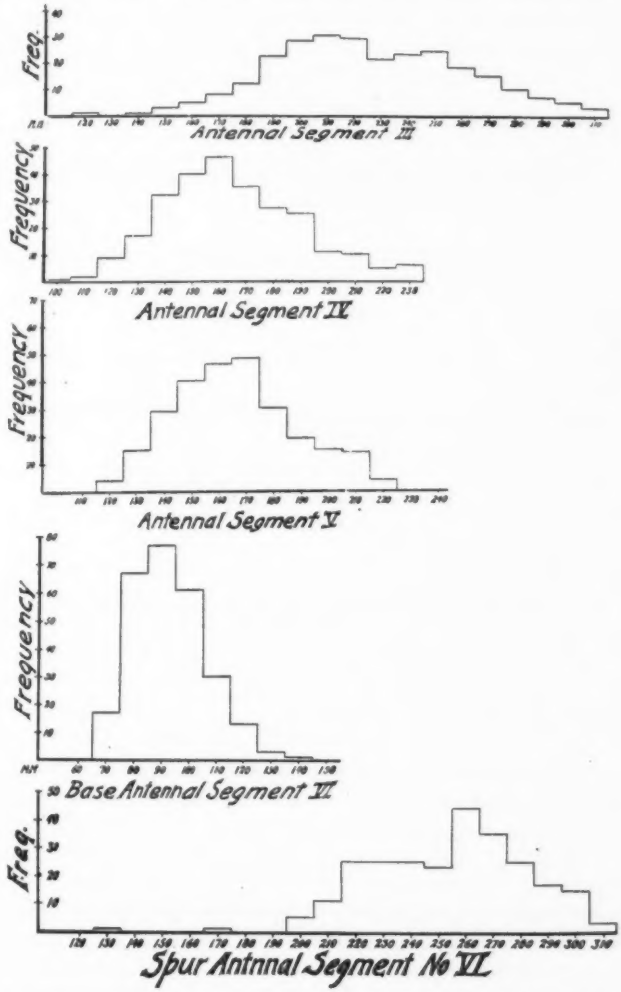


Fig. 2. Histograms illustrating the variability in length of antennal segments in the winged form of Aphis gossypii.

Veronica officinales, *Rumex acetosella*, *Malva rotundifolia*,and *Fragaria virginica*. This mounted, adult material, which included 266 winged viviparæ and 265 wingless viviparæ, was now examined and measurements were taken as follows; (1), the individual antennal segments, (2), the cornicles, (3), the metathoracic tibiæ, and (4), the cubitus vein of the wing. For this purpose a microscope was fitted with an 8 mm. objective and a camera lucida. And these being clamped in pos'tion,

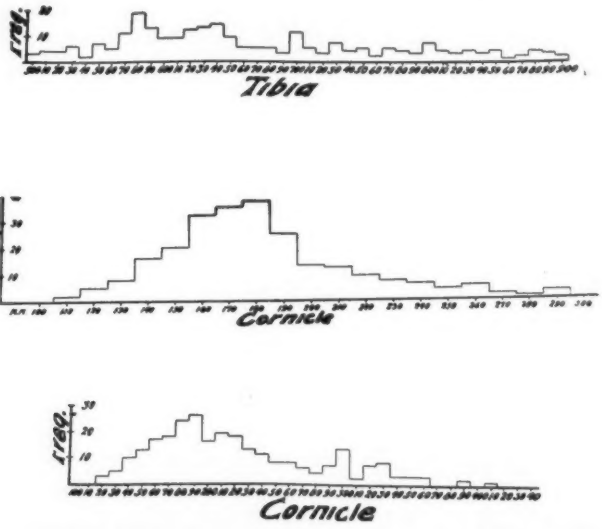


Fig. 3. Histograms illustrating variability in the lengths of the tibia and the cornicle in the alate viviparous form of Aphis gossypii. Histogram illustrating variability in the length of the cornicle in the apterous viviparous form of Aphis gossypii in which the antennal segments are not fused.

the divisions of one millimeter to hundredths was projected on bristolboard and a scale drawn for measuring characters. An antennal segment, for example, being projected at the same magnification as the millimeter scale, could be measured with a very satisfactory degree of accuracy. As all characters examined, with the exception of some of the cubitus veins of the wings and a few tibiæ, were less than one millimeter in length, this scale was quite sufficient for the purpose. The method was employed in making 3,830 measurements.

The Variability of External Characters in Aphis gossypii.

The most obvious variation in this species occurs in the number of antennal segments (Fig. 4) of the wingless form. Of 264 aphids examined, 138 of them, or 52 percent, possessd antennæ made up of five segments, a condition apparently due to fusion of segments III and IV. The remaining 126 aphids possessed antennæ in which segments III and IV were distinct. Tabulating all of the measurements taken according to whether the antennæ were five or six jointed it was found that the fusion of segments of III and IV is correlated with general

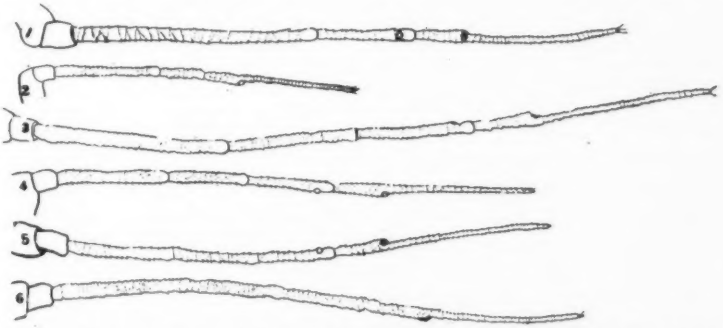


Fig. 4. Illustrating variability in the antennal segmentation of the wingless form of *Aphis gossypii;* 1 and 2, maximum and minimum antennæ of 5 segments. 3 and 4, maximum and minimum antennæ of 6 segments. 5, illustrating the appearance of the antennæ in many specimens of Aphis gossypii in which the segmentation is very indistinct. 6, the antenna of an individual collected from the same colony and mounted at the same time with No. 2.

reduction in length of the body, the cornicles, and the metathoracic tibiæ. But exceptions to this are not difficult to find, and it would be incorrect to express the correlation as being absolute. *In stating the length of external characters for this insect, however, it is evident that a distinction should be made between these two types of the apterous form.* A comparison of the data collected for these two types will serve to illustrate this point. If histograms are constructed from the data obtained by measuring the length of antennal segment V, the base and the spur of antennal segment VI, the tibia, and the cornicle; then, it will be found that the frequency of the distribution differs in these two types of the apterous form. The base of antennal segment VI, for instance, has a mean length

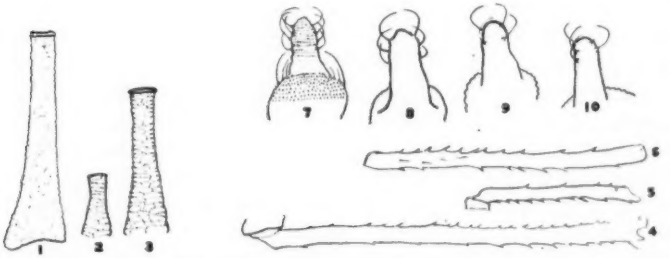


Fig. 5. Illustrating variability of *Aphis gossypii;* 1 and 2, extremes in the length of the cornicles in two apterous forms. 3, the cornicle of an apterous individual collected from the same colony and mounted at the same time with No. 2. 4 and 5, extremes in the length of the tibia of apterous forms. 6, the tibia of the same individual from which cornicle No. 2 was taken. 7, 8, 9, and 10, are variations in the size, shape, number, and position of caudal hairs in the apterous form, in which it should be noted that the highly distinctive, incurved, terminal extremity of the most posterior hairs is characteristic throughout the series.

of .080 mm. in the 138 aphids having III and IV of the antenna fused, and the mean length of the base in the 126 individuals with III and IV distinct is .100 mm. while the average length of the base in the 264 aphids, if a general average is taken, is .094 mm. To illustrate graphically the influence of this fusion of segments III and IV, histograms were constructed to show the frequency in distribution of the data taken for these two types (reference should be made to them in Figures 1, 2, and 3).

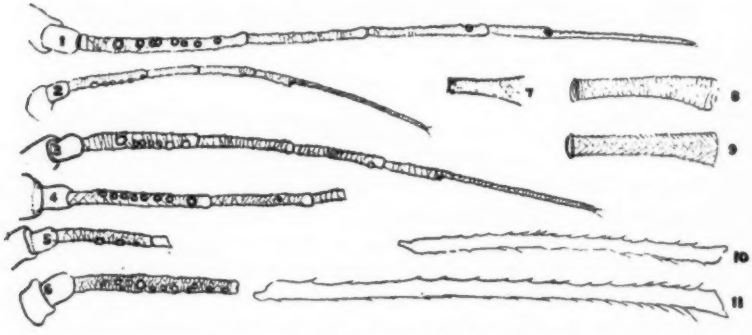


Fig. 6. Illustrating variability in the winged form of *A. gossypii.* 1 and 2, extremes in the length of the antenna. 3, the average appearance, number, position, and distribution of the sensoria. 4, the sensorium appears occasionally on segment IV. 5 and 6, extremes in the number of sensoria. 7 and 8, extremes in the length of the cornicle. 9, the cornicle of an individual taken from the same colony from which No. 7 was taken. 10 and 11, extremes in the length of the metathoracic tibia.

Furthermore, it should be noted that the fusion of III and IV is not equal to the combined length of the two segments. The average length of III was found to be .224 mm., of IV it was .160 mm. and these combined (.385 mm.) are in excess of the average length of III and IV in the fused condition, (.286 mm.). Thus it will be seen that in the latter type of the apterous form, the total length of the antenna is shortened since the reduction is not made up by segments V and VI.

The variability of the apterous form of *A. gossypii* was given additional attention in the matter of the length of the antennal segments, the tibiæ and the cornicles, and the data obtained are expressed in frequency histograms and are summarized in the following tables:

TABLE I.

Extremes in the variation of length of external characters found in the apterous viviparous form of 264 individuals of the species, *Aphis gossypii*. The data given here are selected on the basis of the possession of either 5 or 6 antennal segments, referred to as the fused or the unfused type.

Unit	Fused Type				Unfused Type			
	Maximum	Aphid No.	Minimum	Aphid No.	Maximum	Aphid No.	Minimum	Aphid No.
Ant. Seg. III	.444	476-6	.155	571-0-8	.428	571-Q-12	.138	571-Q-7
Ant. Seg. IV	.....	.....	.....	.....	.244	571-K-1	.031	486- 2
Ant. Seg. V	.224	571-K-1	.095	571-Q-4	.218	571-K-1	.104	571-Q-6
Ant. Seg. Base VI	.137	476- 6	.067	571-C-4	.202	571-Q-12	.072	498- 5
Ant. Seg. Spur VI	.320	571-K-1	.132	573- 8	.340	481- 3	.204	571-Q-6
Tibia	1.008	571-K-1	.453	571-Q-4	1.027	571-K-1	.414	585-A-6
Cornicle	.346	475- 1	.115	571-Q-4	.413	571-K-1	.133	587- 1

TABLE II

The average length of the external characters found in a study of 264 individuals of the apterous viviparous form of Aphis gossypii. The means are selected according to antennal type.

Unit	Average	Fused Type Mean	Unfused Type Mean
Ant. Seg. III	.224	.....	.240
Ant. Seg. IV	.160	.....	.150
Ant. Seg. V	.140	.120	.170
Ant. Seg. Base VI	.094	.080	.100
Ant. Seg. Spur VI	.254	.260	.270
Tibia	.675	.580	.700
Cornicle	.238	.180	.190
Ant. Seg. III, IV	.385	.....	.390
III, IV Fused	.286	.260	.....

Reference should be made to the material in figures 4 and 5 illustrating extremes in length of these characters.

The alate, or winged form of *Aphis gossypii* was examined in the same manner. Measurements were taken of Antennal segments, III, IV, V, and the base and spur of VI, the cornicle, the tibia, and the cubitus vein of the wing. In addition, the number of sensoria on right and left segment III was noted. Text figures of extreme and normal conditions are offered in figures 5 and 6 and the data obtained from measuring the external characters of 266 alate individuals are expressed in frequency histograms (figures 2 and 3) and are summarized in the following tables:

TABLE III

Extremes in the variation of length of external characters found in a study of 265 individuals of the alate viviparous form of Aphis gossypii. This is accompanied by a list of the various aphids from which these measurements were taken.

Unit	Maximum	Aphid No.	Minimum	Aphid No.
Ant. Seg. III	.325	588-2-1	.119	498- 6
Ant. Seg. IV	.235	571-L-2	.102	571-Q-3
Ant. Seg. V	.227	571-K-2	.115	571-Q-3
Ant. Seg. Base VI	.127	571-K-2	.077	571-Q-3
Ant. Seg. Spur VI	.375	571-K-2	.237	571-5-3
No. Sensoria, R	12.	573- 4	3.	571-Q-2
No. Sensoria, L	12.	639- 7	4.	571-Q-3
Tibia	1.079	583- 1	.462	571-Q-9
Cornicle	.292	648-C-1	.112	571-Q-14
Cu Wing	1.895	593- 1	.647	571-L-1

TABLE IV

The average and the mean lengths of external characters determined in a study of 265 individuals of the alate viviparous form of Aphis gossypii. Reference should also be made to the material in figure 6 illustrating extremes in the length of these characters.

Unit	Average	Mean
Ant. Seg. III	.241	.210
Ant. Seg. IV	.174	.160
Ant. Seg. V	.173	.170
Ant. Seg. Base VI	.107	.090
Ant. Seg. Spur VI	.307	.260
No. Sensoria, R	7.2	.....
No. Sensoria, L	7.2	.....
Tibia	.818	.700
Cornicle	.192	.180
Cu Wing	1.008	.....

Correlation of External Characters for Length.

Having established the extent of the variation of the external characters of *Aphis gossypii*, let us consider the value of these parts as key characters. An examination of the frequency histograms expressing the variability of the apterous viviparous form will reveal in several instances fairly normal curves, and it would appear that dependable correlation exists between two

Table V

Correlation surface for the length of the base compared with the length of the spur of antennal segment VI. The data are taken from 116 individuals of the apterous viviparous form in which antennal segments III and IV were not fused.

Length of Antennal Segment VI—Base	Length of Antennal Segment VI—Spur										
	210–219	220–229	230–239	240–249	250–259	260–269	270–279	280–289	290–299	Total
60–69				1	1					2
70–79	1		3	0	2	2			1	9
80–89		4	3	3	4	10	5	3	4	36
90–99		2	3	3	3	4	9	6	7	37
100–109			1		2	7	4	2	5	21
110–119			1			2		3	5	11
120–129										
Total	1	6	11	7	12	25	18	14	22	116

or more characters which might be useful in establishing the identity of the insect. But this is misleading. Reference to Table I indicates that little relation exists between the growth of any two external organs or parts of organs. It will be noted that the maximum and minimum dimensions constituting this table are not taken from a single large, or a single small aphid, but that it is a composite, no duplicate of which was found in nature. The data represent rather, the limits of growth of any one segment or organ. Absence of uniform growth in this aphid was confirmed in a study of the coefficient of correlation of external characters.

Assuming from the frequency of distribution, as well as from the terminal position and the function of antennal segment VI, that the growth ratios of its two component parts, the base and the spur, might be comparatively uniform, a correlation surface was determined for the length of the base and the

TABLE VI.

Correlation surface for the length of the spur of antennal segment VI compared with the length of the cornicle. The data is taken from 123 individuals of the apterous viviparous form in which antennal segments III and VI are not fused.

Length of Cornicle	Length of Antennal Segment VI Spur (3 and 4 Not Fused).															
	200–209	210–219	220–229	230–239	240–249	250–259	260–269	270–279	280–289	290–299	300–309	310–319	320–329	330–339	340–349	350–359	Total
120–129																	
130–139				1													1
140–149	1	1					1	2					1				3
150–159	1	1	1														6
160–169		1		2		1						1					5
170–179				1		1		1			1						4
180–189			1	1		1	6	2				1					12
190–199			2	1		1	2	1	1								8
200–209			2	1	1	1	1	2	2	1							11
210–219																	0
220–229			1	1		3	3	4									12
230–239			1			1		1	1			1					5
240–249				1	1						1						3
250–259							2	1	1								4
260–269				1			2		1	1	2						7
270–279								1									1
280–289							1		2	1		1					5
290–299				1			2	1	1		1						6
300–309				1	1				1	1							4
310–319							1	1		1			1				4
320–329			1		1		2				1						5
330–339							1	1	1	1	2						6
340–349					1		3	1	1	1			2	1	1		
Total	2	3	9	12	5	9	24	19	12	8	8	3	4	1	1		

length of the spur of segment VI. The data for this comparison, taken from the apterous type in which III and IV are not fused, are shown in Table 5.

From Table 5 was derived a more definite statement of the extent of the variability of the growth ratios of the base and the spur. The mean length of the base is found to be .094 mm. and its standard deviation from the mean is .0115. The mean length of the spur is found to be .267 mm. and its standard

deviation from the mean is .021. Computing the coefficient of correlation for the base and the spur we have, Rxy = .0217 ± .062 a figure so small as to indicate that no correlation exists at all. Thus, we arrive at the conclusion that the factor governing the growth of the base of segment VI has no relation to that factor which limits the rate or extent of growth of the spur of the same segment. And concomitant with this is the fact that these two are valueless as "key characters."

TABLE VII.

Correlation surface for the length of the metathoracic tibia compared with the combined lengths of antennal segments III and IV. The data are taken from 119 individuals of the apterous viviparous form in which antennal segments III and IV are not fused.

Combined Lengths of Ant. Segs. III, IV	Length of Tibia.																		
	500–524	525–549	550–599	575–599	600–624	625–649	650–674	675–699	700–724	725–749	750–774	775–799	800–824	825–849	850–874	875–899	900–924	925–949	Total
200–224	1				1			1											3
225–249				1															1
250–274		3	4	3	1				1										12
275–299	2		2	1	5	2	1									1			14
300–324				1	2	4	3												10
325–349					1	4	3	2	3										13
350–374						2	1	5	4	1	1								13
375–399									1	1	1		1	1					5
400–424									1	3	3	3	3	2	2				17
425–449											1	3	2	3	3	3	1		16
450–474											3	1	1	1					6
475–499															1		1	1	3
500–524													1				1		2
525–549																1		2	3
	3	3	6	6	10	12	8	8	10	5	9	7	8	7	6	5	3	3	

The length of the cornicle as compared with the length of the spur of antennal segment VI offers another possibility as a key character in aphids and the relationship was determined. The data for the comparison, taken also from the apterous type in which segments III and IV are not fused, are shown in Table 6.

From these data, computation discloses little of value in these characters for determining the species under consideration. The coefficient of correlation, Rxy = .4496 ± .0613, is again so small as to indicate that practically no dependable correlation exists between the lengths of these two characters.

Some promise of key value was offered by comparing the lengths of the tibiæ and the combined lengths of segments III and IV in the unfused type of the apterous form. The data for comparison are shown in Table 7.

The figures in this instance offer somewhat more promise in the correlation table, and computation reveals a coefficient of correlation of .08691±.0149 which indicates a very close relation between the factors governing the growth ratios of

TABLE VIII.

Correlation surface for the length of the base compared with the length of the spur of antennal segment VI. The data are taken from 263 individuals of the alate viviparous form of Aphis gossypii.

LENGTH OF ANTENNAL SEGMENT VI—SPUR	LENGTH OF ANTENNAL SEGMENT VI—BASE.						
	.070–.079	.080–.089	.090–.099	.100–.109	.110–.119	.120–.129	Total
.230–.239				1			1
.240–.249							0
.250–.259		2		3			5
.260–.269	1	4	4	6	1		16
.270–.279			10	9	3	1	23
.280–.289		4	9	14	5	1	33
.290–.299		1	11	19	7	1	39
.300–.309			12	26	14	6	58
.310–.319		1	3	18	12	3	37
.320–.329			2	8	10	6	26
.330–.339			1		6	2	9
.340–.349			1	2	1	3	7
.350–.359				1	1	1	3
.360–.369					1	2	3
.370–.379					3		3
Total	1	12	53	107	64	26	263

these organs. It would appear, therefore, that this is a fairly dependable character and as such it is an exception in an aphid characterized by remarkable variability.

This tendency in individual segments or appendages to vary independently is illustrated in Table I but is more noticeable in an examination of summarized data. The condition seems to be one in which an aphid may be endowed with a large tibia even though the body, cornicles, and most of the antennal segments, are small, or it may be the possessor of a large pair of cornicles while the tibiæ, body, and antennal segments are

comparatively small, and so on. No explanation of this seeming lack of proportion is immediately apparent. It appears to have a nutritional basis and it might be ventured that, since the embryo tends to develop to uniform proportions, the rapidity of growth of embryos may not be commensurate with the food intake, especially during nymphal stages of the viviparous mother. If the physiological balance in this species is adjusted with respect to reproduction rather than to the

TABLE IX.

Correlation surface for the length of antennal segment IV compared with the length of antennal segment V. The data are taken from 266 individuals of the alate viviparous form of Aphis gossypii.

Length of Antennal Segment V	Length of Antennal Segment IV.														
	100–109	110–119	120–129	130–139	140–149	150–159	160–169	170–179	180–189	190–199	200–209	210–219	220–229	230–239	Total
110–119		1													1
120–129	1	1	4												6
130–139	1	1	6	9	2	1	2	1							23
140–149			6	12	10	8									36
150–159				5	11	12	8	5	1						42
160–169					7	12	15	15	5		1				55
170–179					2	7	13	4	7	1	2	1			37
180–189						4	2	6	10	1	3	2			28
190–199								1	3	4	1	3	1		13
200–209								1	2	2	2	3	2		12
210–219									2	1	1	2	2	1	9
220–229											1	1	2		4
Total	2	3	16	26	32	44	40	33	30	9	11	12	7	1	266

development of adult characters, then such a condition of variability as exists in Aphis gossypii might be expected. However, this is entirely hypothetical.

The coefficient of correlation here, $Rxy = .4689 \pm .0328$, is too low for utilization of these characters.

More promise, however, is indicated for antennal segments IV and V in the alate viviparous form and the data for the comparison of these two segments are shown in Table 9.

Here the coefficient of correlation is unusually high, being expressed $Rxy = .9275 \pm .0057$ and there is every indication that the relationship of these two characters constitute a highly valuable means of distinguishing the species when used in conjunction with other characters.

Variability and the Foodplant.

In order to determine the extent of the tendency of the summer forms of Aphis gossypii to vary on its different foodplants, data were assembled from colonies of the insect that were kept on several of its common hosts. Collections were mounted on various dates as previously described and since these collections included not only representatives of the aphids of average size, but also the largest and the smallest individuals at that time, it was possible to obtain a comparison of the influence of several foodplants on the variability of this species. Table 10 summarizes the data.

Table X.

Extremes of variability of the apterous viviparous form on various foodplants. The data are taken from individuals in which the antennal segments III and IV are not fused.

	Cucumber		Squash		Begonia		Oenothera	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Ant. Seg. III	315	234	428	138	238	157	261	125
Ant. Seg. IV	226	031	194	100	163	115	160	095
Ant. Seg. V	196	130	107	114	167	118	166	107
Ant. Seg. Base VI	090	081	202	081	106	084	107	072
Ant. Seg. Spur VI	340	226	234	206	319	255	247	240
Tibia	955	585	867	588	732	566	735	496
Cornicle	359	194	302	152	231	160	203	141
Ant. Total	1,167	702	1,165	639	993	729	941	639

It should be noted in table 10 that the greatest variation between the largest and the smallest aphids taken on these plants occurs in those taken from squash. It is of interest to note that both of these individuals were taken on the same day, November 11, 1923. The least amount of variation occurred on Oenothera, where, again the two extremes were taken at the same time. It would be illogical, however, to attach any especial significance to the degree of variability observed here. The aphids grown on Oenothera are somewhat smaller than those produced on squash but they are unusually variable just the same. So far as available data show there is nothing to indicate that Aphis gossypii is not an unusually variable insect no matter what foodplant it happens to colonize.

SUMMARY.

1. Mounted specimens of Aphis gossypii (adult) were examined and measurements were taken of the individual antennal segments, the cornicle, metathoracic tibia, and the cubitus vein of the wing. The material so examined and measured included 266 winged viviparæ and 265 wingless viviparæ.

2. Of the wingless viviparæ 52% were found to possess antennæ made up of five segments, a condition apparently due to fusion of antennal segments III and IV. The remaining 48% of the wingless viviparæ were found to bear antennæ made up of six distinct segments.

3. It is apparent that the same factor which causes fusion of antennal segments III and IV usually causes reduction in the length of the body, the cornicle, and the metathoracic tibia.

4. The maximum and minimum dimensions of the external structures in this insect were found to be separated by unusually wide limits. The extent of the variation is set forth in frequency histograms, comparative tables, and illustrative figures.

5. A study of the correlation of the dimensions of the external structures indicates that there is an absence of uniform growth rate throughout the insect and that little correlation exists in the rate of growth of any two parts. The condition seems to be one in which an aphid may be endowed with a large tibia even though the body, cornicles, and most of the antennal segments, are small. Or, it may be the possessor of a large pair of cornicles while the tibiæ, body, and antennal segments are comparatively small, and so on. No explanation of this seeming lack of proportion is immediately apparent.

6. An exception to the foregoing was found in the apterous viviparous form in which antennal segments III and IV are not fused. Here, correlation was found to be fairly constant between the combined length of antennal segments III plus IV and the length of the metathoracic tibia, the tibia being consistently more than twice the length of III plus IV.

7. In the alate viviparous form correlation was found to exist between the length of antennal segments IV and V.

8. While somewhat greater diversity in size occurs among individuals inhabiting squash than among those colonizing

oenothera, the tendency to vary is exhibited in a pronounced degree and this was found to be true of the species on the several host plants from which the material was taken. There is nothing to indicate that *Aphis gossypii* is not an unusually variable insect no matter what food-plant it happens to colonize.

9. A technical description of Aphis gossypii based on the data of this study may be useful in establishing the exact identity of this insect.

TABLE XI.

The external characters of *Aphis gossypii;* the mean lengths as indicated in a study of 266 winged viviparæ and 265 wingless viviparæ. The means for the number of sensoria on the right and on the left antennæ are also given. This table may be used in establishing the identity of *Aphis gossypii.*

	Apterous Viviparae.		Alate viviparæ
	Fused Form*	Unfused Form	
III	.286	.240	.210
IV		.150	.160
V	.120	.170	.170
VI—Base	.080	.100	.090
VI—Spur	.260	.270	.260
Sensoria R			7.
Sensoria L			7.
Tibia	.580	.700	.700
Cornicle	.180	.190	.180
Cubitus vein			1.008

*Apparently III and IV fused.

BOOK REVIEW.

THE INSECTS OF AUSTRALIA AND NEW ZEALAND, by R. J. Tillyard; 560 pages, 1,256 figures, including eight colored plates with 261 figures. Published by Angus and Robertson, Ltd., Sydney, Australia.

This is the most remarkable general text of entomology that has appeared recently in that it gives the entomological world for the first time a general view of the many curious and interesting insects of the Australian region. The reader has paraded before his vision a long series of wierd living fossils that have been preserved in Australia since its isolation in the early Tertiary. The volume includes keys to all families with a statement of the number of species known in each in Australia and New Zealand, usually also giving one or more excellent figures of species in the family. With few exceptions, all figures are original, many of the text figures having been made by the author, while Mrs. Tillyard painted the beautiful colored plates. The text figures are especially valuable in emphasizing exact morphological character. The volume represents much more labor than is usually put into such a work as the author had no preceding text to follow and nearly all keys had to be written directly from Australian material because of the many primitive forms that as connecting links would not fit into keys already developed in Europe and America. The book is beautifully printed, a variety of type having been used cleverly and artistically.

C. H. KENNEDY.